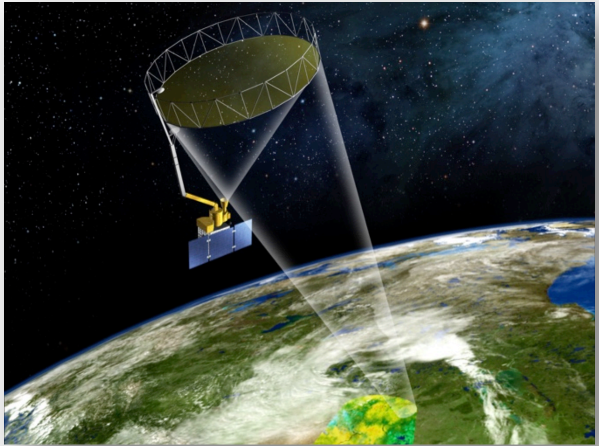
National Aeronautics and Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET



Introduction to SMAP

Jul. 20, 2016

Outline

1. Mission objectives
2. Instruments and algorithm approach
3. Products
4. Calibration and Validation
5. Applications

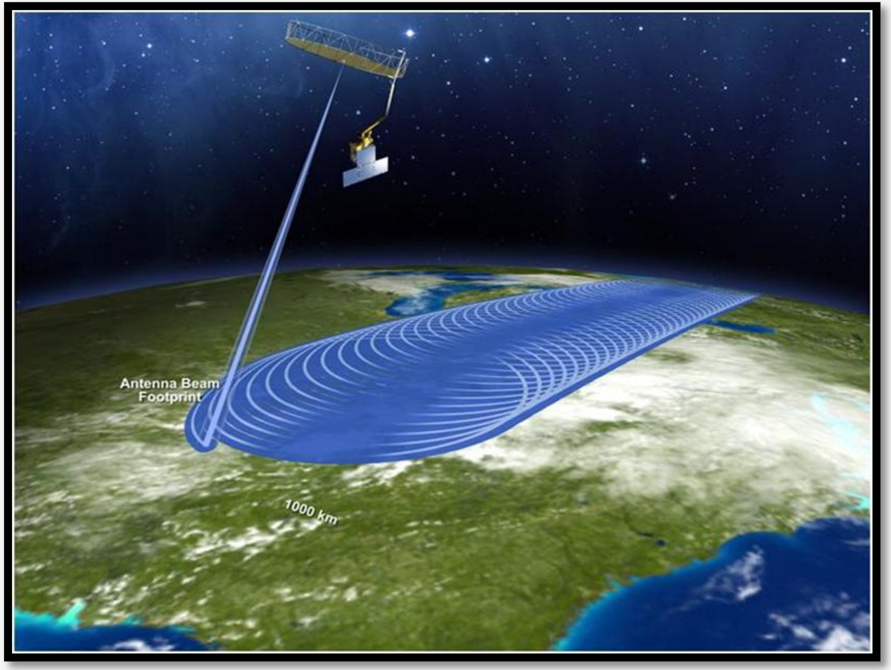
Mission Overview and Objectives

NASA Satellite Fleet

Fuente: NASA Goddard Visualization Lab

SMAP Overview

Instruments



Launched on Jan. 31, 2015

Radar (no longer working)

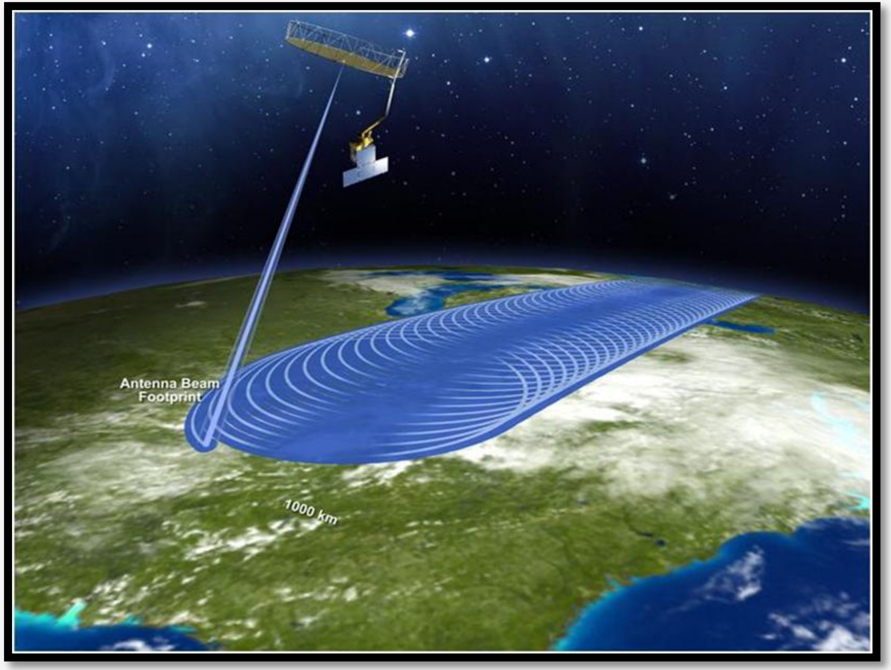
- Frequency: 1.26 GHz
- Polarization: VV, HH, HV
- Resolution: 3km
- Relative Accuracy: 1.0 dB (HH and VV), 1.5 dB (HV)

Radiometer

- Frequency: 1.41 GHz
- Polarization: H, V, 3^{rd} & 4^{th} Stokes
- Resolution: 40km
- Relative Accuracy: 1.3K

SMAP Overview

Instruments



Lanzamiento: 31 de enero del 2015

Shared Antenna

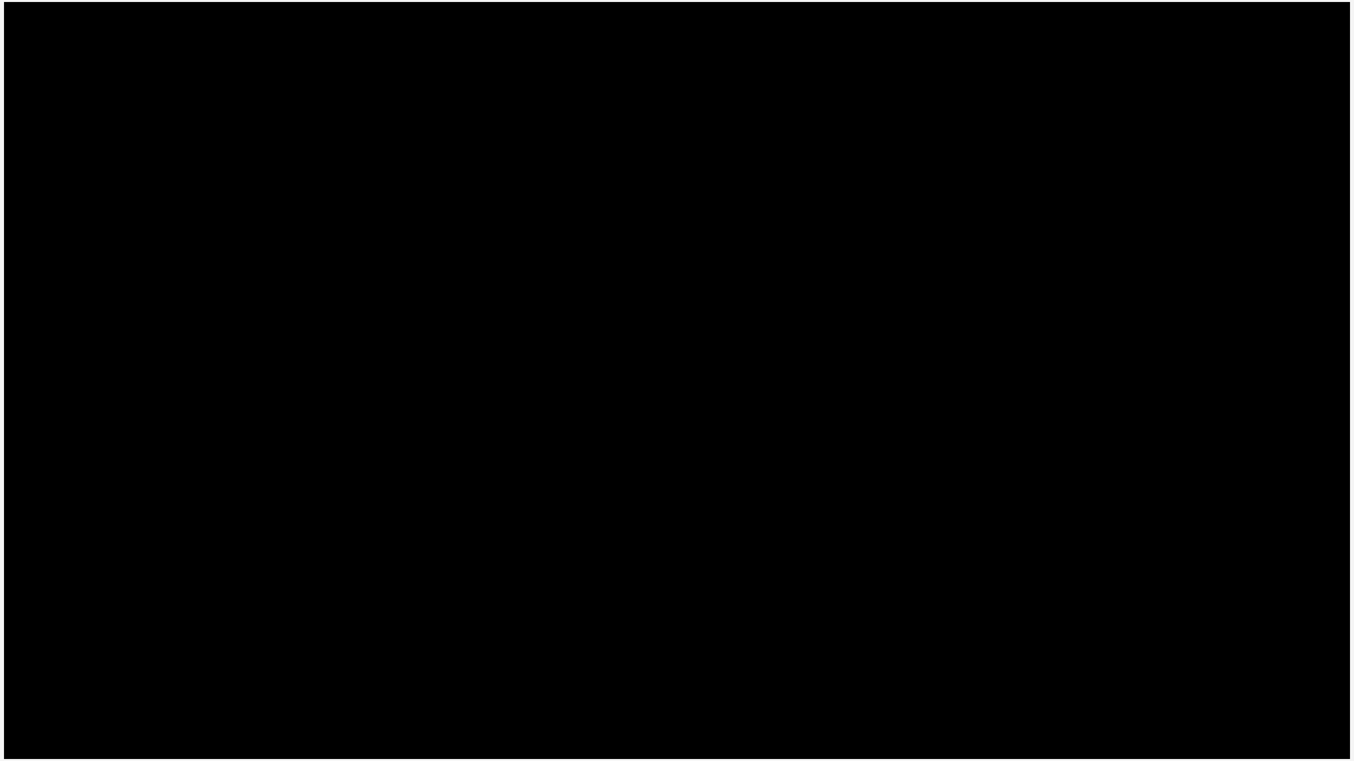
- 6m diameter
- Conical scanning at 14.6 r.p.m.
- Constant incidence angle: 40 degrees
- Swath 1000km – wide
- Swath and orbit allow global coverage every 2-3 days

Orbit

- Sun synchronous, 6 am/pm orbit
- **685km** altitude

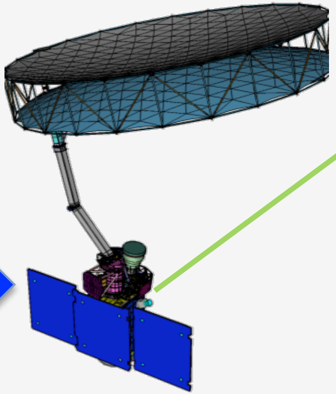
Mission Duration: 3 years

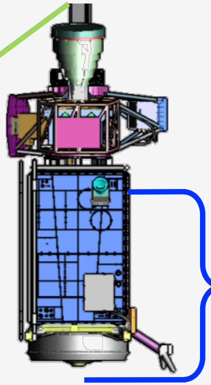
SMAP- Animation



Mission Design

Delta II 7320-10C





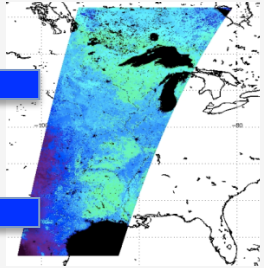
Communication Network

Data Validation

Control Center and Data Processing (JPL/GSFC)

Soil Moisture and Freeze/ Thaw Products

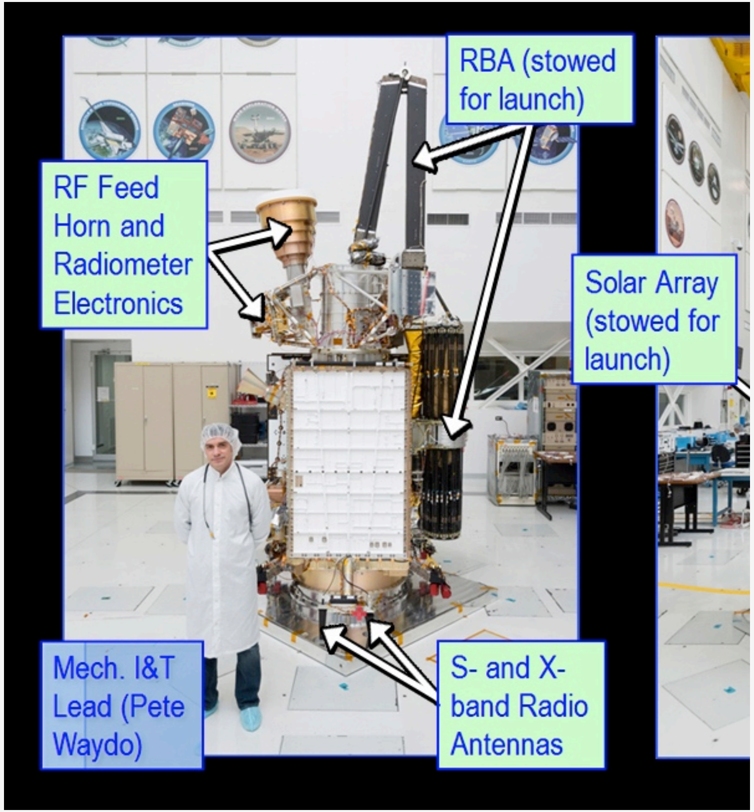
Scientific Products



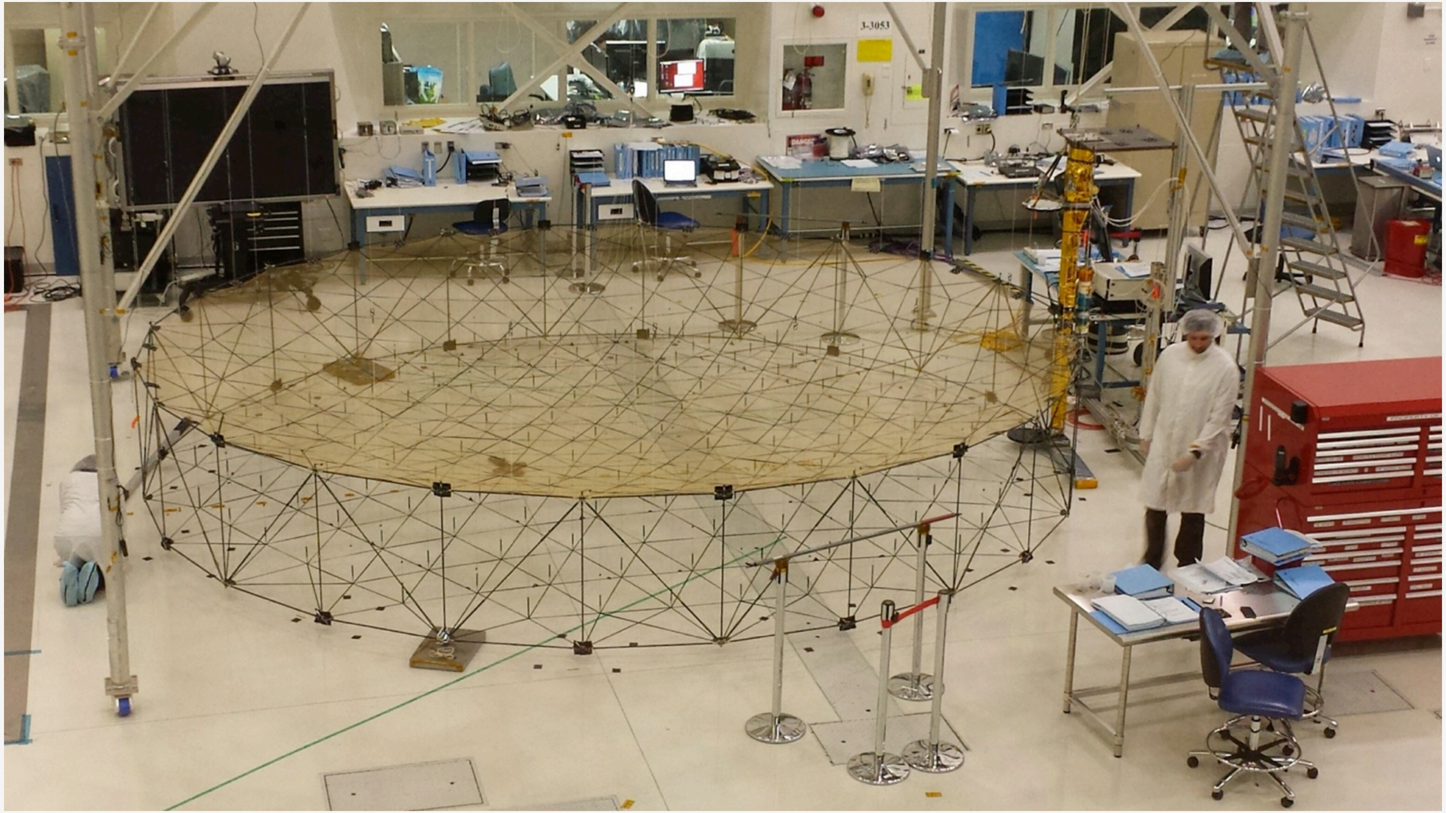
Alaska Satellite Facility Data Center (Radar products – L1)

NSIDC (all other products

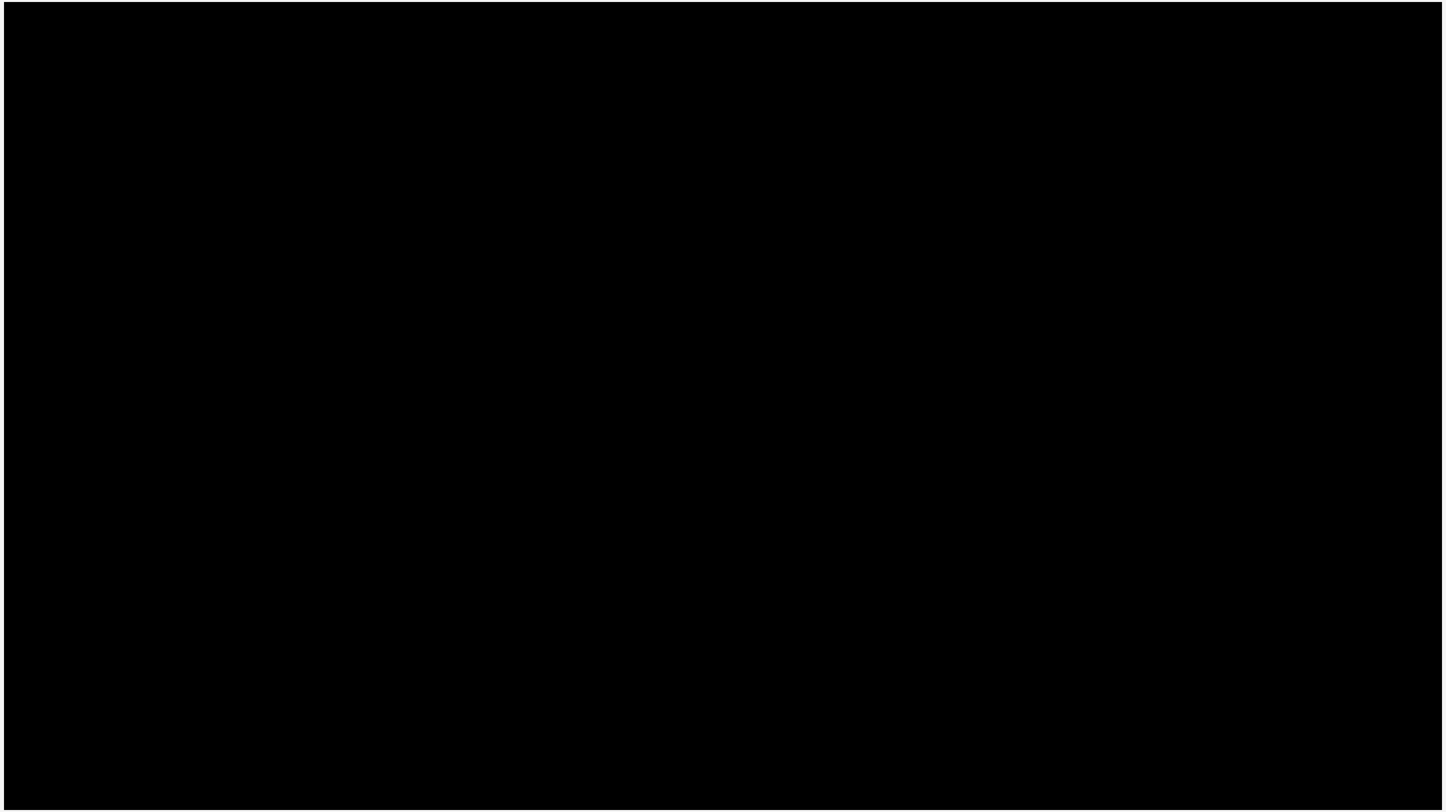
SMAP


RBA (stowed for launch)
RF Feed Horn and Radiometer Electronics
Solar Array (stowed for launch)
Mech. I&T Lead (Pete Waydo)
S- and X-band Radio Antennas

SMAP Antenna

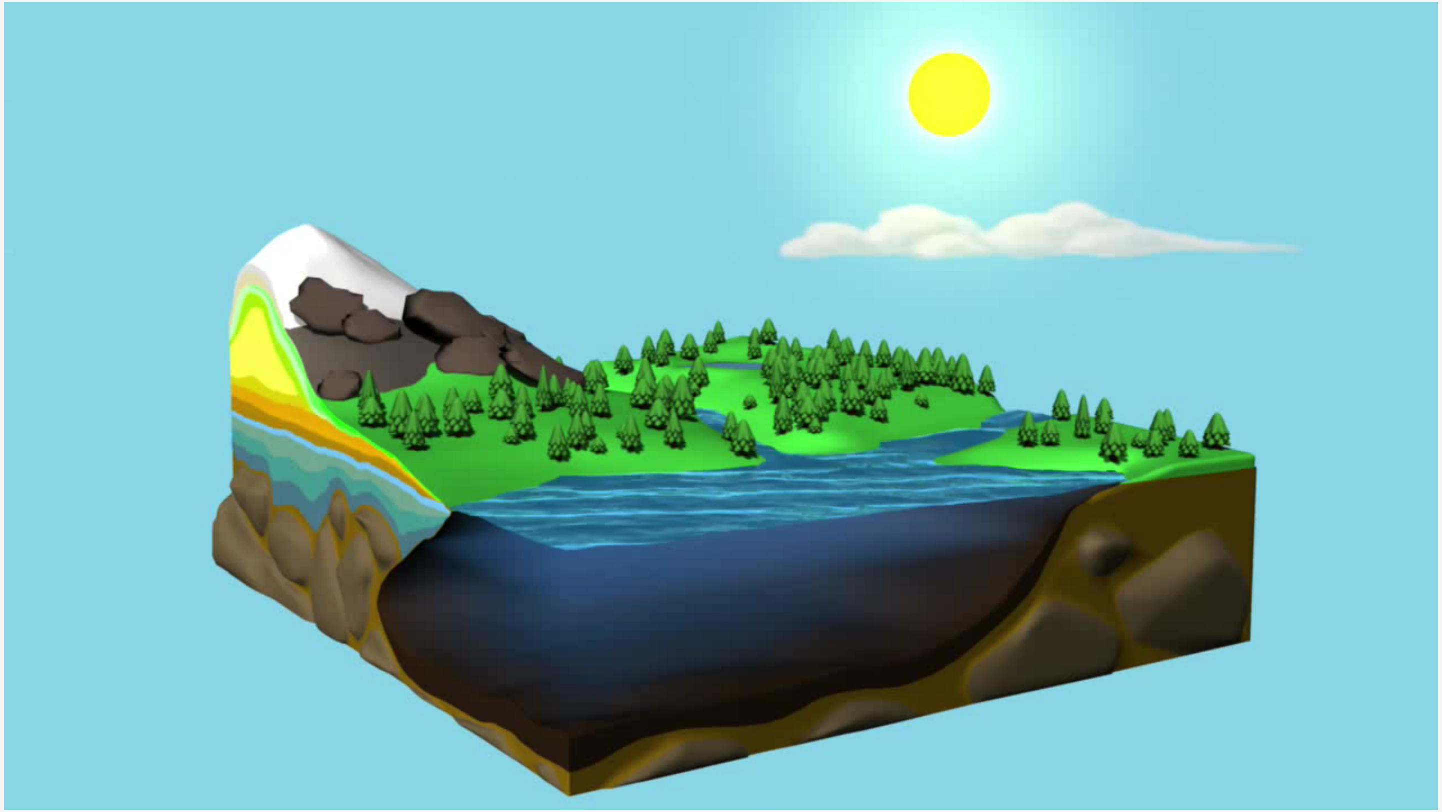


Testing the SMAP Antenna

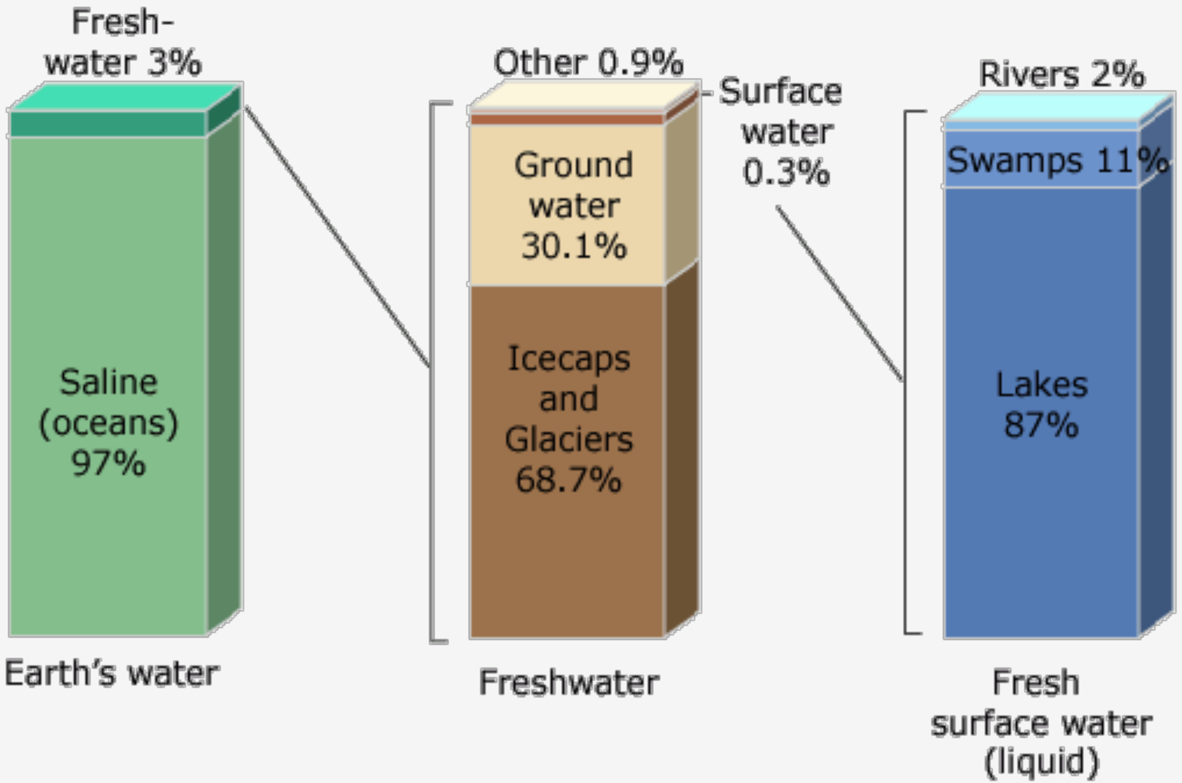


Why SMAP

The Water Cycle

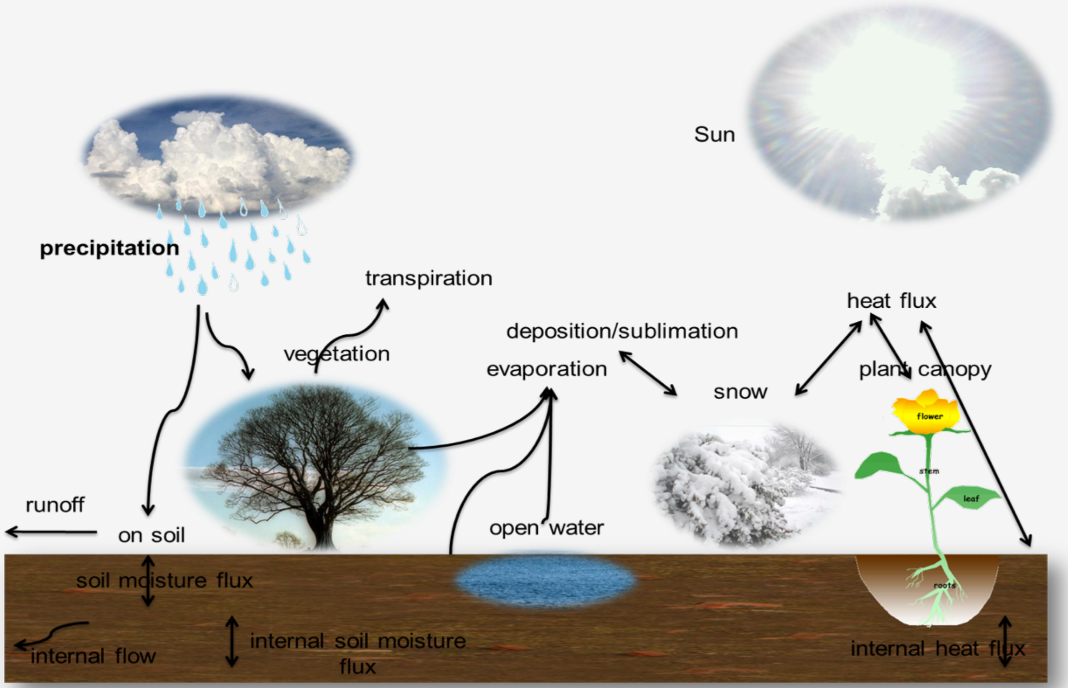


Water Distribution on Earth



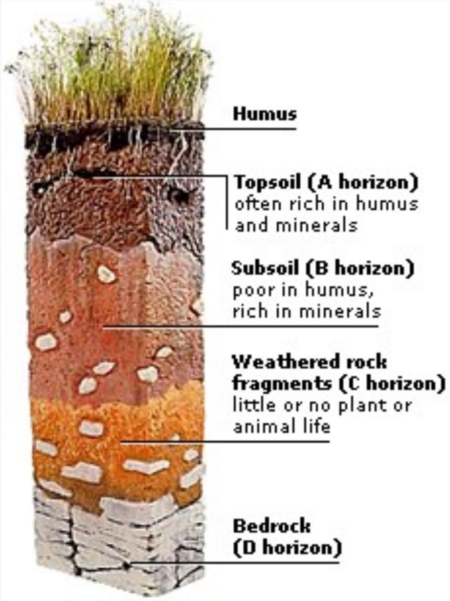
The Importance of Soil Moisture

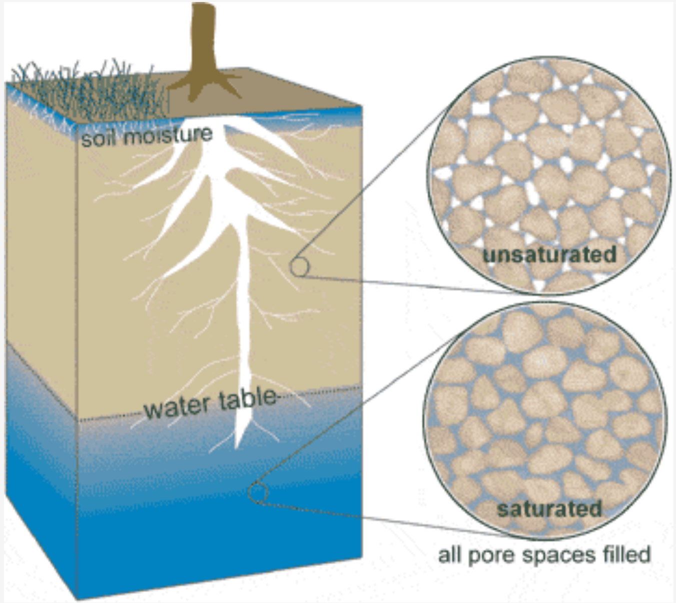
For each kilogram of water on earth, <u>only one milligram</u> is stored as soil moisture. Yet this miniscule amount of water exerts *significant* control over various hydrological, ecological and meteorological processes.



(Chen et. al., 1996, 1997; Chen and Dudhia, 2001; Ek et. al., 2003; Koren et. al., 1999)

Soil Profile





Factors Influencing Soil Moisture

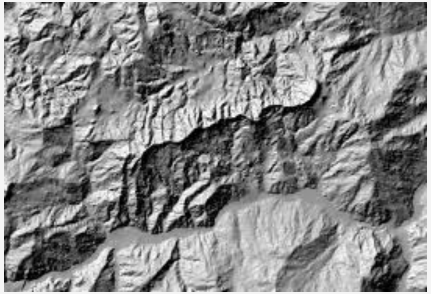
Soil Moisture varies with space and time.
Primary factors that influence distribution of soil moisture:

Rainfall

Soil Texture

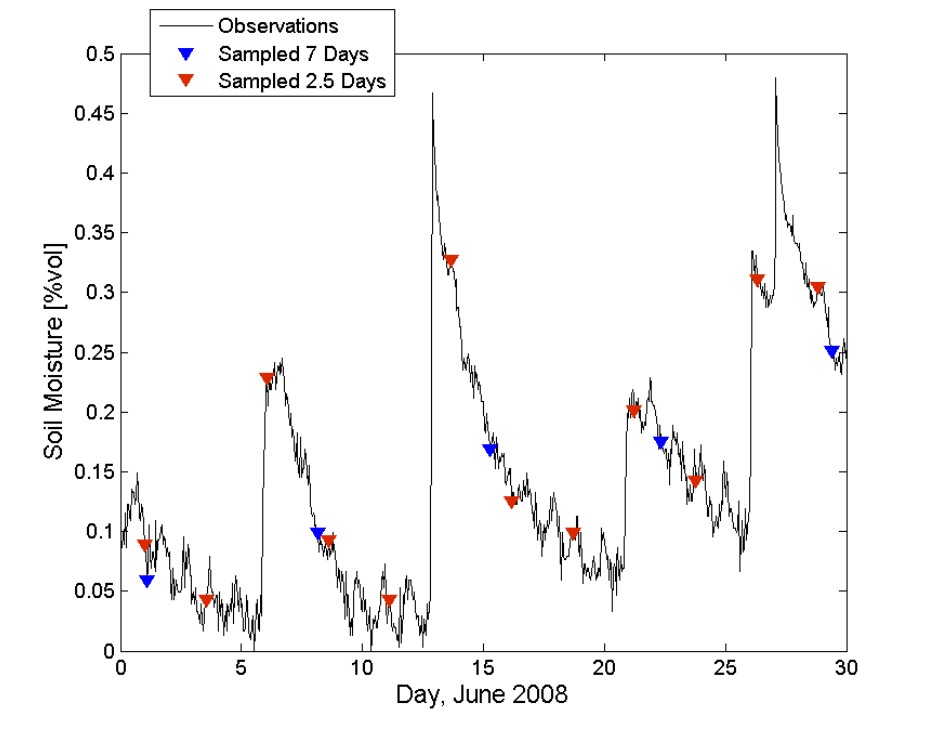
Vegetation

Topography



Justification for Observations Every 3 Days

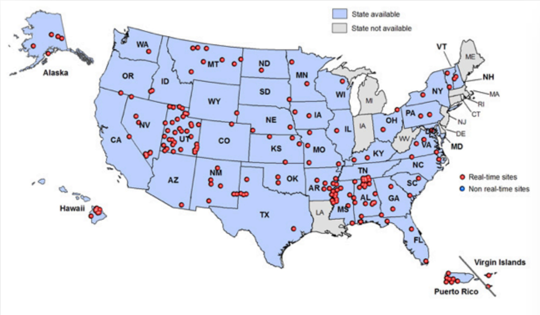
- Observations are needed every 3 days or less to optimally determine the variability in soil moisture.



Primary Objectives of SMAP

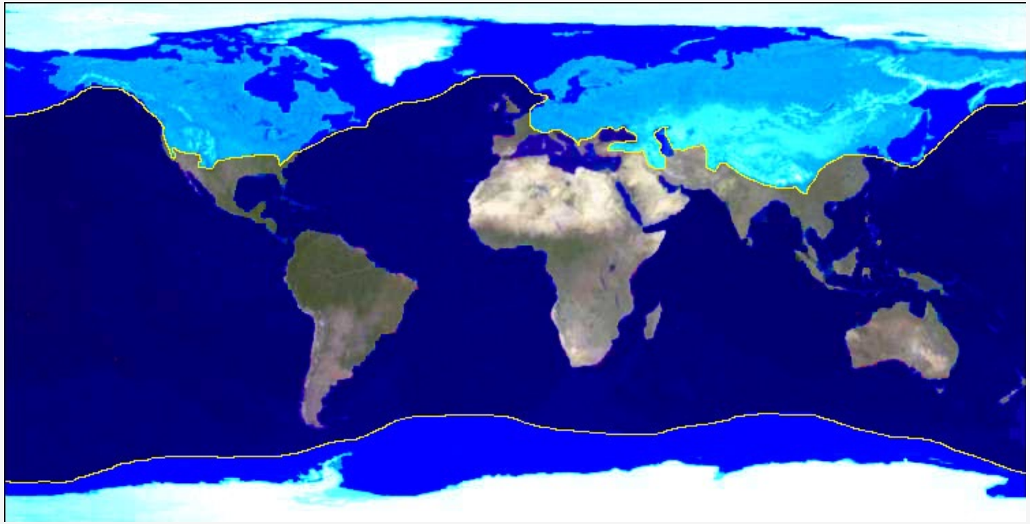
Soil Moisture and Freeze/Thaw State

- Limitations in measuring soil moisture:
  - In situ measurements of soil moisture are few and far between.

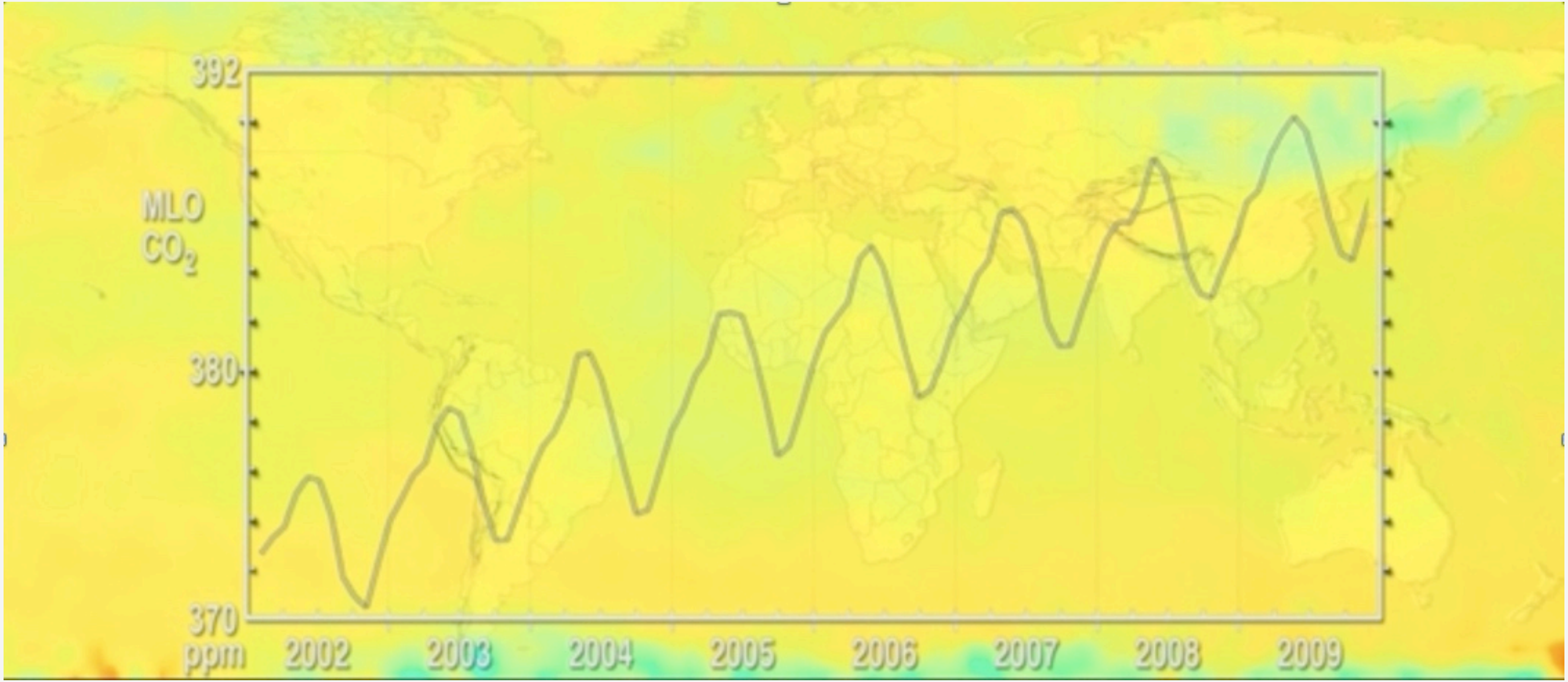


- SMAP supported science and applications
  - Understand processes that link the terrestrial energy, water, and carbon cycles
  - Estimate global water and energy terrestrial fluxes
  - Quantify net carbon fluxes in the northern high latitudes

Importance in Knowing the Freeze/Thaw State of the Land Surface



Average Global Atmospheric CO2 Concentrations



SMAP Requirements

Requirement	Soil Moisture	Freeze/ Thaw
Resolution	~~9~~ **and 36 km**	~~3~~ km
Refresh Rate	3 days	2 days[1]
Accuracy	**0.04** [cm^3/cm^3] [2]	80% [3]
Duration	36 months	

[1] North of 45°N Latitude
[2] % volumetric water content, 1-sigma
[3] % classification accuracy (binary: Freeze or Thaw)

SMAP Requirements

Product Short Name	Description	Resolution
L3_FT_HiRES	Global daily mosaic of surface freeze/ thaw state	1-3 km
L3_SM_P	Global daily mosaic of soil moisture–radiometer	36 km
L3_SM_AP	Global daily mosaic of soil moisture–radar and radiometer	9 km
L4_SM	Surface and root zone soil moisture	9 km
L4_C	Net carbon exchange	9 km

SMAP Status

- Loss of the SMAP Radar
  - On July 7 2015 the SMAP radar suddenly stopped operating (after having collected data for 2.5 months)
  - A team was formed to determine the cause
  - The high power amplifier was identified as the cause
  - Efforts were made to configure the system in different ways with no success
- Implications for SMAP
  - Surface freeze/thaw state product at 3 km will not be produced
  - Soil moisture products at 9 km will not be produced

Soil Moisture Products from Different Satellites

- SMAP - L-Band, 40 km, observations every 3 days

https://nsidc.org/data/smap/smap-data.html

- SMOS - L-Band, 40 km, observations every 3 days

https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/news/-/article/smos-level-2-soil-moisture-data-now-available-via-eumetcast-in-near-real-time

- ASCAT - L-Band, 50 km, observations every 2 days

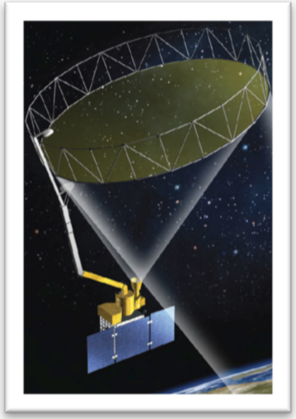
http://rs.geo.tuwien.ac.at/dv/ascat/

Uniqueness of the SMAP Radiometer

Operational L-Band satellite radiometers:

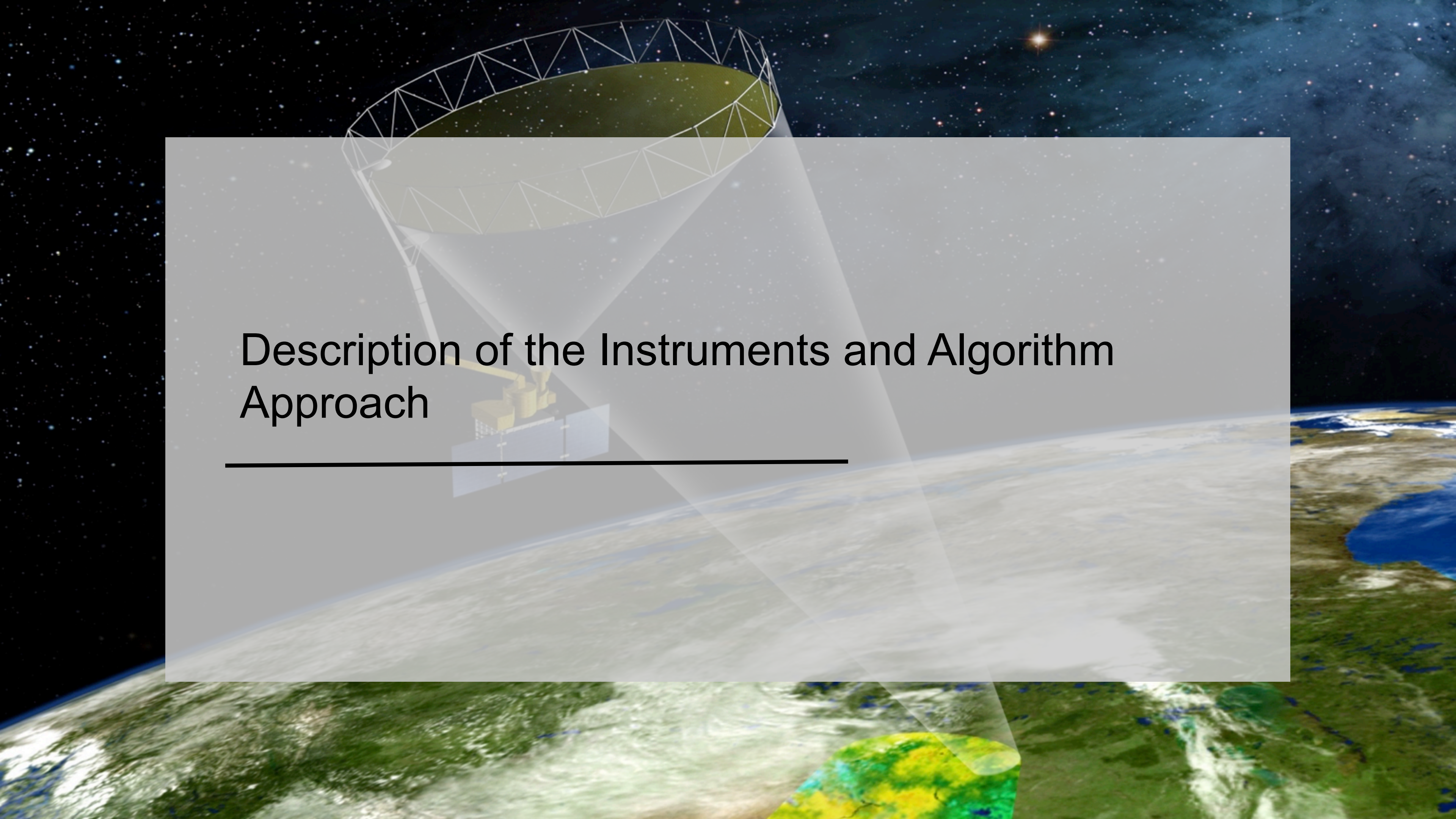
SMOS – ESA satellite
Launched: Nov. 2009
L-band radiometer
Spatial resolution: 40 km
Temporal Resolution: 3 days
Sensing depth: ~5 cm

SMAP satellite
Launched: Jan. 2015
L-band radiometer
Spatial resolution: 40 km
Temporal Resolution: 3 days
Sensing depth: ~5 cm



Uniqueness of SMAP:

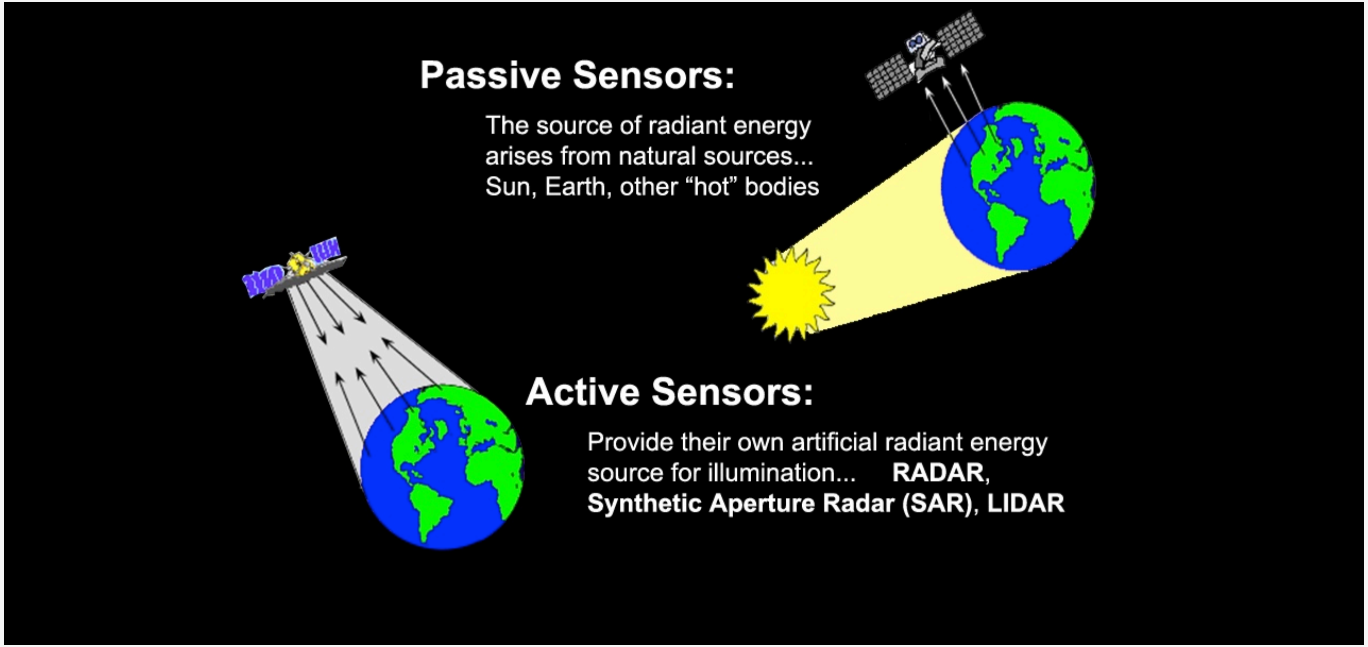
1. Aggressive Approach to Radio-Frequency Interference (RFI) Detection and Mitigation
2. Constant incidence angle



Description of the Instruments and Algorithm Approach

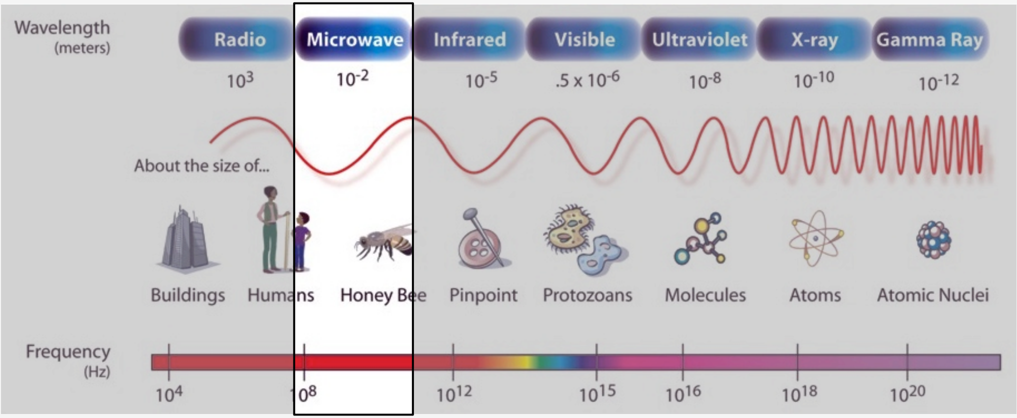
Passive and Active Remote Sensing

SMAP uses active and passive sensors to measure soil moisture



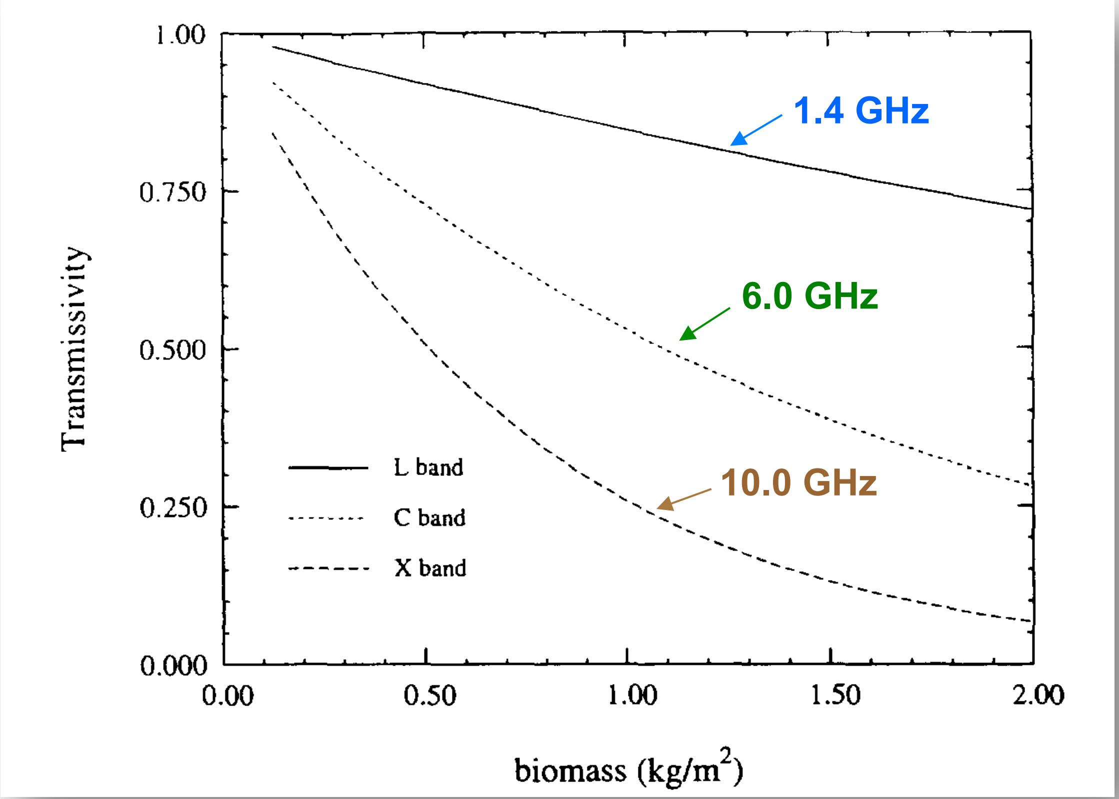
Microwave Remote Sensing

- With Visible and Infrared sensors the soil is masked by clouds and vegetation. Optical sensors operate by measuring scattered sunlight and are “daytime only”.
- Microwaves can penetrate through clouds and vegetation, operate day and night, and are highly sensitive to the water in the soil due to the change in the soil microwave dielectric properties.



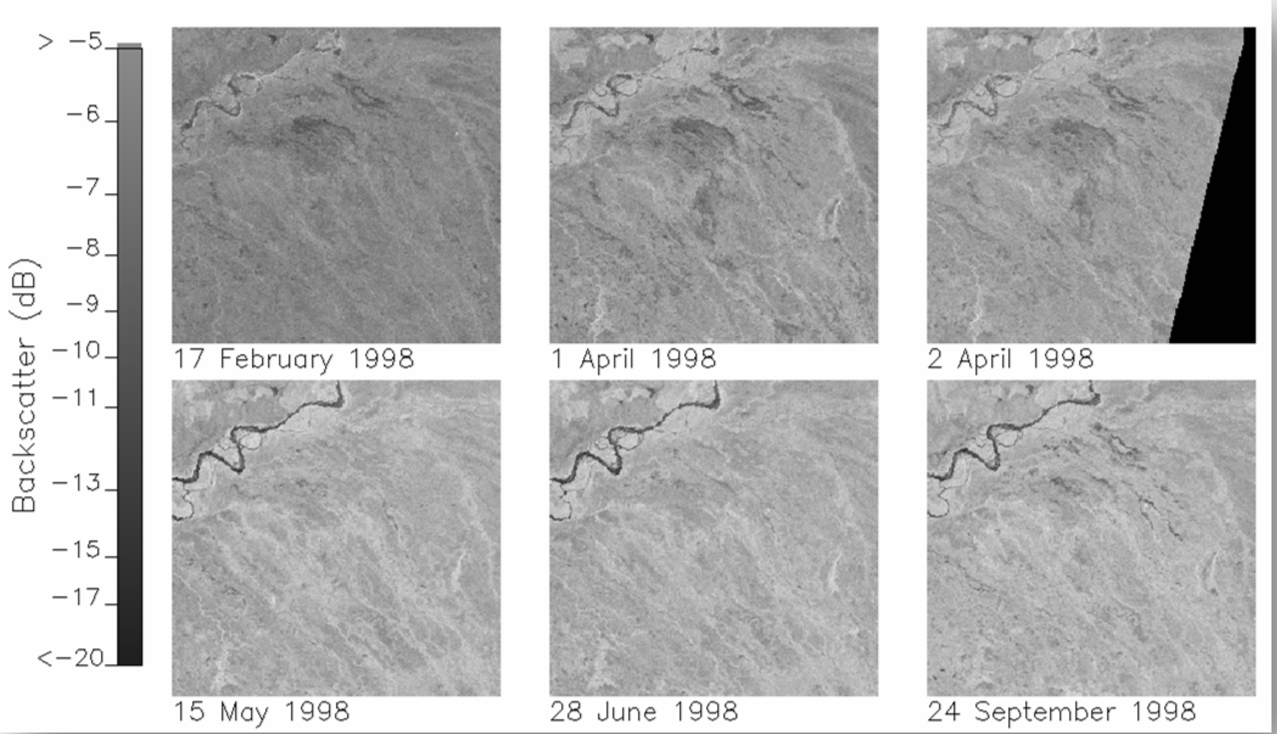
Advantages of L-Band

Vegetation attenuation increases as frequency increases

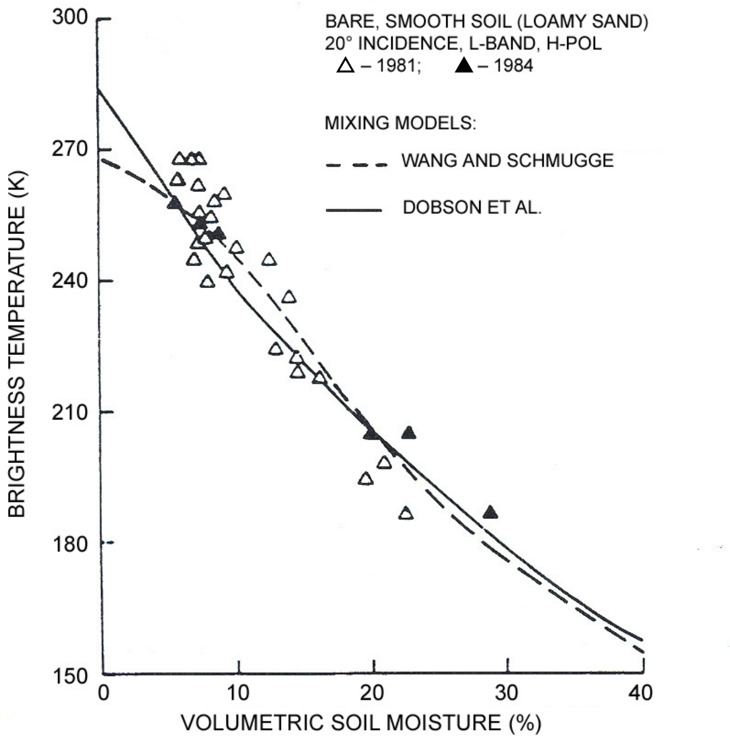


Land Surface Dielectric: Surface Freeze/Thaw State

As the land surface transitions from frozen to thawed, there is a large change in dielectric producing a notable increase in radar backscatter, on the order of 3 dB.



Relation Between Brightness Temperature and Soil Moisture



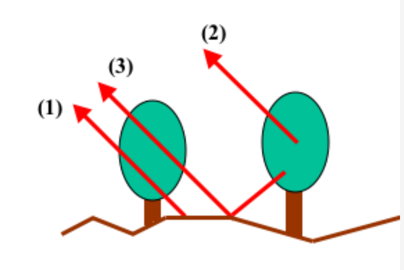
[Jackson and O'Neill, *IEEE TGARS, GE-25*, 1987.]

Measurement Approach

- p = H, V (radiometer) y pq = VV, HH, HV (radar)
- Contributions from the: soil, vegetation, and soil-vegetation interaction
- Soil moisture is the dominant contributor to the signal
- Soil moisture measurements are corrected for the effects of vegetation, surface roughness and temperature

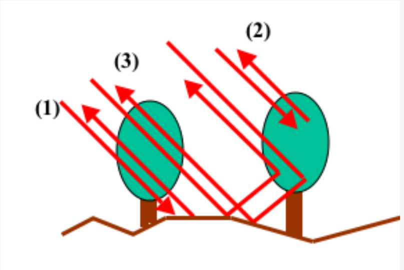
Emission

$$T_{Bp}^{t} = T_{Bp}^{s} L_p + T_{Bp}^{v} + T_{Bp}^{sv}$$



Backscatter

$$\sigma_{pq}^{t} = \sigma_{pq}^{s} L_{pq}^{2} + \sigma_{pq}^{v} + \sigma_{pq}^{sv}$$

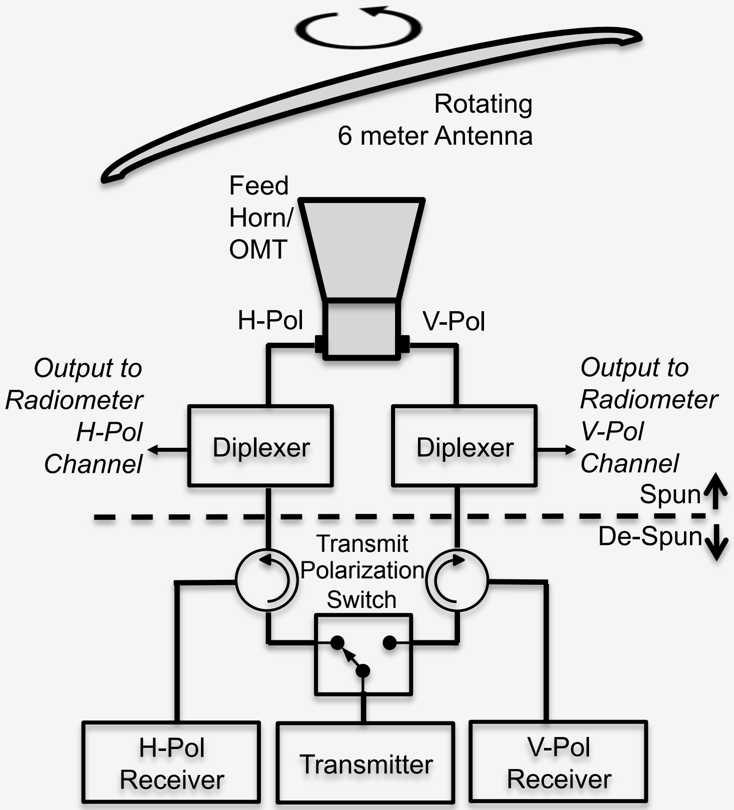


Ancillary Data Sources

Ancillary data are used to estimate the key unknown parameters: surface temperature (≈ surface air temp. at 6 am), vegetation opacity, surface roughness and soil texture

Parameter	Description/Sources
Surface air meteorology	- Data assimilation (GEOS/DAO) - Forecast models (NCEP and ECMWF)
Vegetation opacity	- Vis/IR satellite-derived NDVI, LAI, landcover (MODIS, IGBP-DIS) - Historical phenology (AVHRR)
Surface topography	- Digital elevation models (USGS and SRTM)
Soil texture	- Soils databases (Global, NGDC; US, STATSGO)
Land/water boundaries	- Coastal boundaries and inland water bodies (NGDC)

Radar and Radiometer Operation



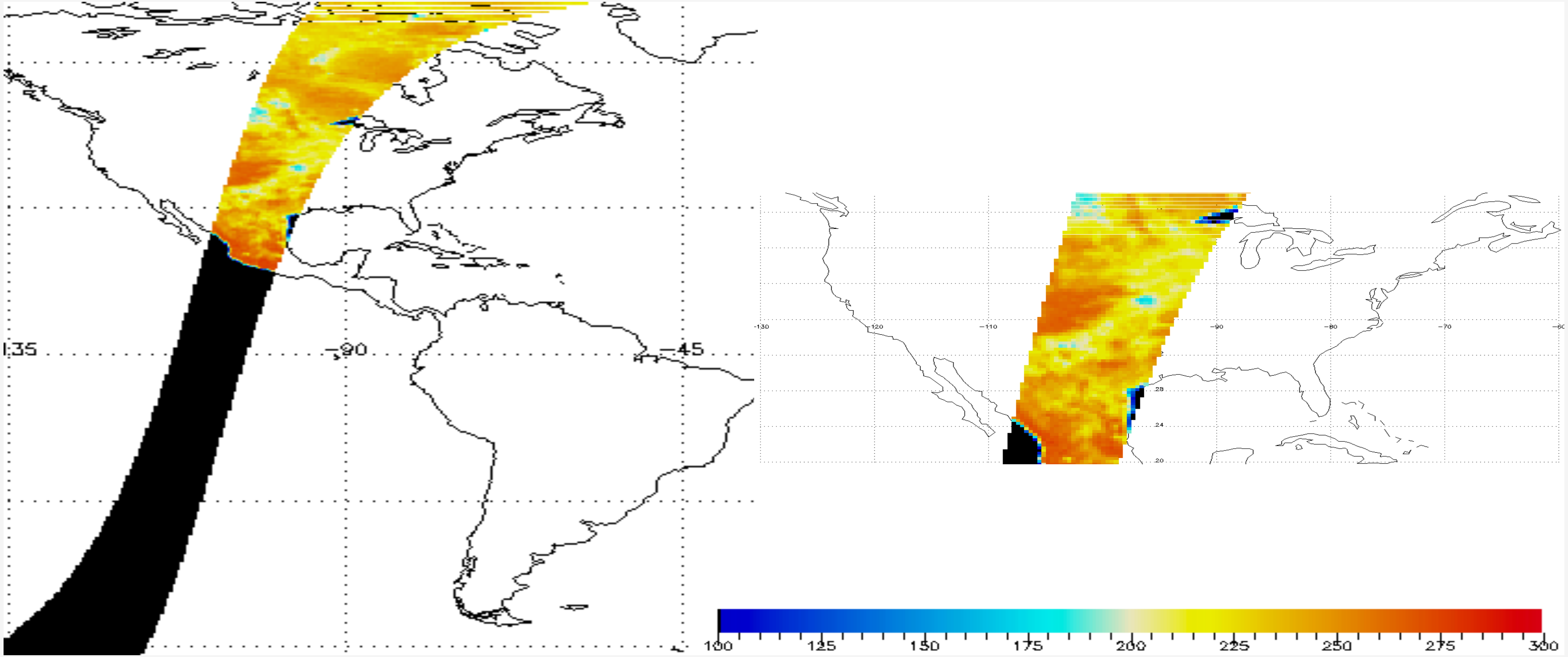
SMAP Products

Data Product Short Name	Description	Grid Resolution	Granule Extent
L1A_Radar	Parsed Radar Instrument Telemetry		Half Orbit
L1A_Radiometer	Parsed Radiometer Instrument Telemetry		Half Orbit
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	Half Orbit
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1 km	Half Orbit
L1B_TB	Radiometer T_B in Time Order	39x47 km	Half Orbit
L1C_TB	Radiometer T_B	36 km	Half Orbit
L2_SM_A	Radar Soil Moisture (includes Freeze-Thaw)	3 km	Half Orbit
L2_SM_P	Radiometer Soil Moisture	36 km	Half Orbit
L2_SM_AP	Active-Passive Soil Moisture	9 km	Half Orbit
L3_FT_A	Daily Global Composite Freeze/Thaw State	3 km	North of 45° N
L3_SM_A	Daily Global Composite Radar Soil Moisture	3 km	Global
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	36 km	Global
L3_SM_AP	Daily Global Composite Active-Passive Soil Moisture	9 km	Global
L4_SM	Surface & Root Zone Soil Moisture	9 km	Global
L4_C	Carbon Net Ecosystem Exchange	9 km	North of 45° N

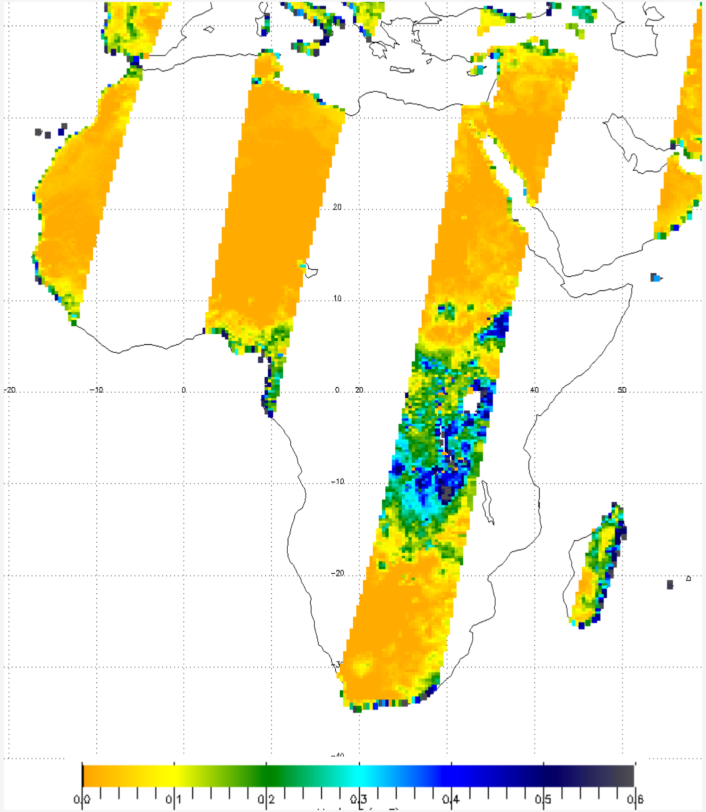
Data Product Design

- **All products are in HDF5 format**
  - Each SMAP HDF5 file contains the primary data parameters (e.g., soil moisture, freeze/thaw, sensor data) and all data used in the production of those primary parameters. These files also include metadata, geolocation information, quality flags, etc.
- **Projection: EASE-Grid 2.0**
  - Equal-area projection
  - Level 2, 3, 4, and radiometer L1C are in this projection
- **Values**
  - Radiometer data (brightness temperature) is in Kelvin
  - Radar data is in sigma naught
  - Soil moisture is a volumetric measurement expressed as cm^3/cm^3
  - Freeze/thaw is a binary measurement, either frozen or thawed
  - Net ecosystem exchange is in grams of carbon/square meter per day

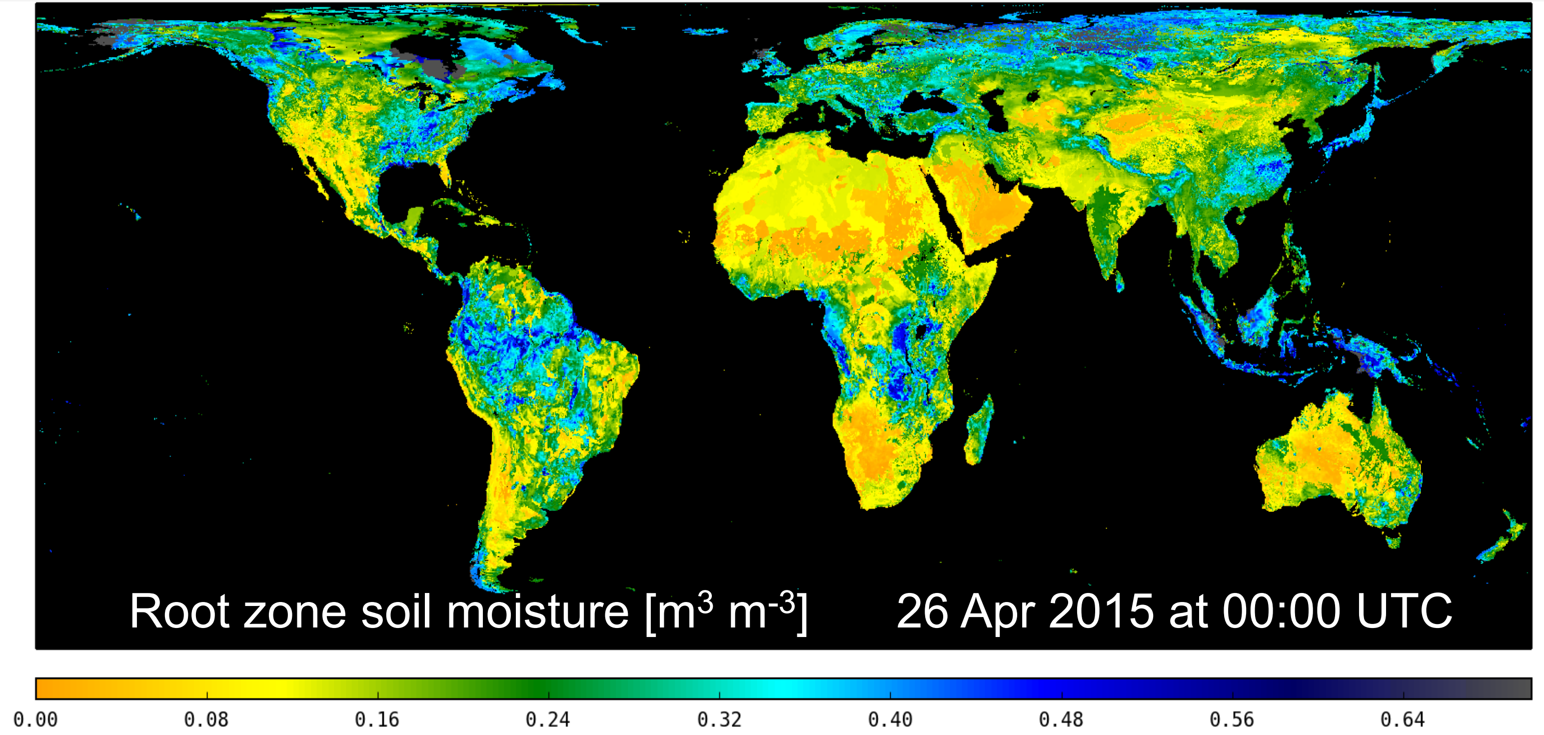
Radiometer Data – Level 1C



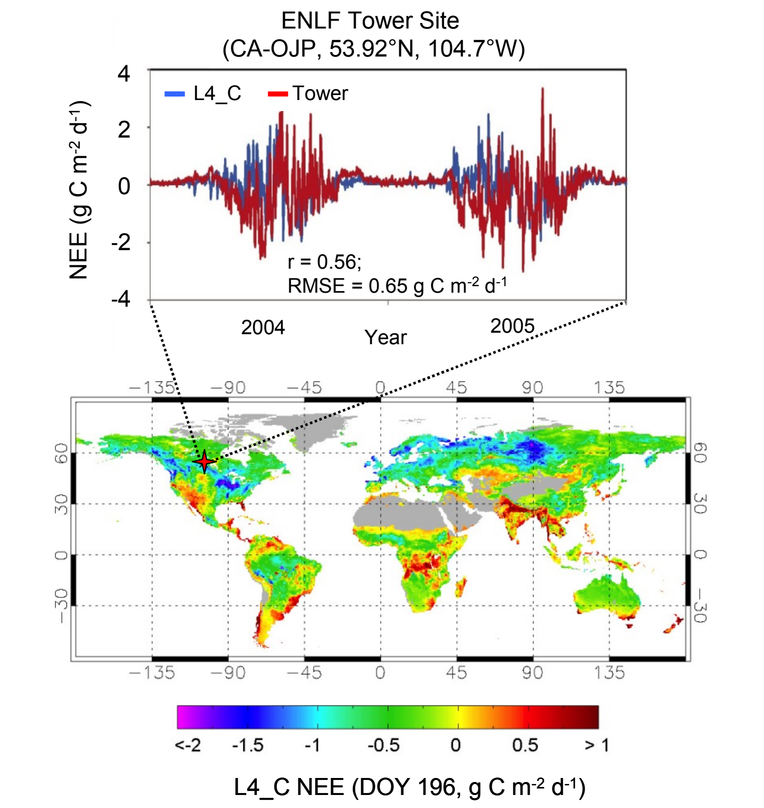
Soil Moisture Derived from the Radiometer- Level 3



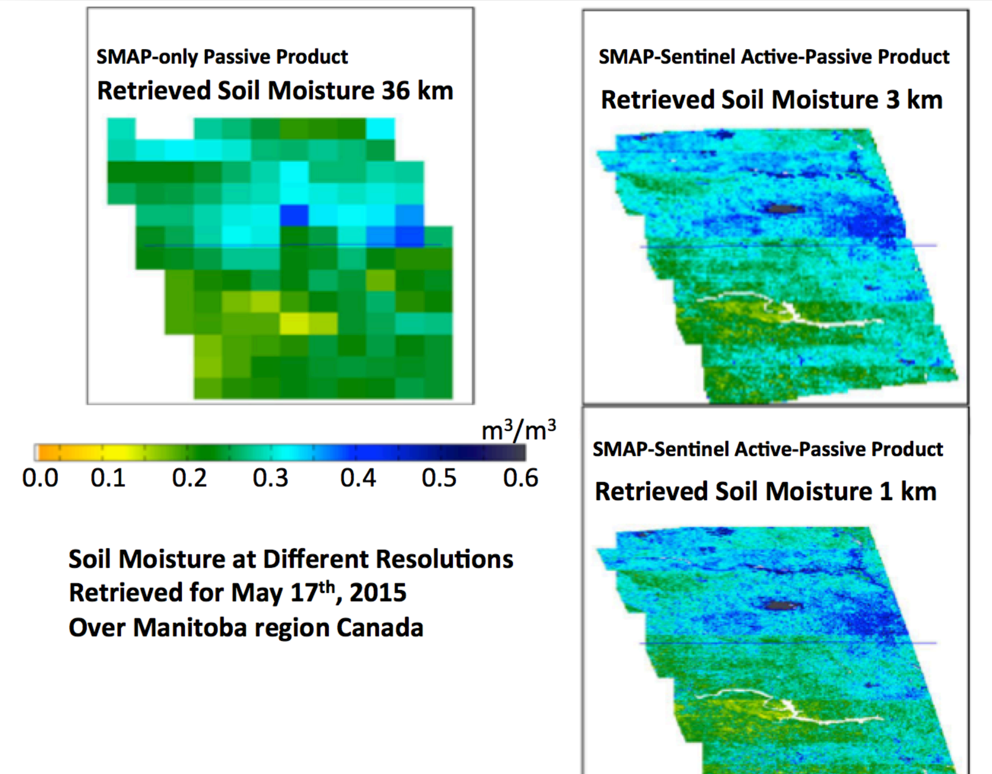
Surface and Root Zone Soil Moisture- Level 4



Net Ecosystem Carbon Exchange- Level 4

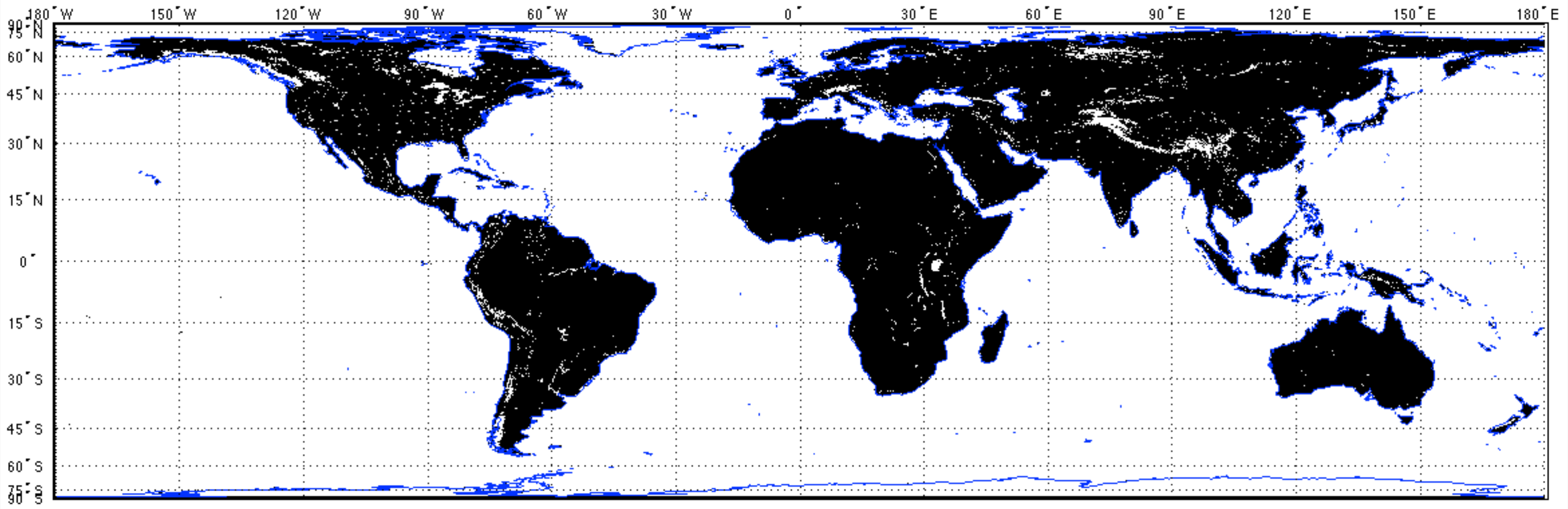


SMAP Enhanced Active-Passive Product Using Sentinel



Source: Narendra Das

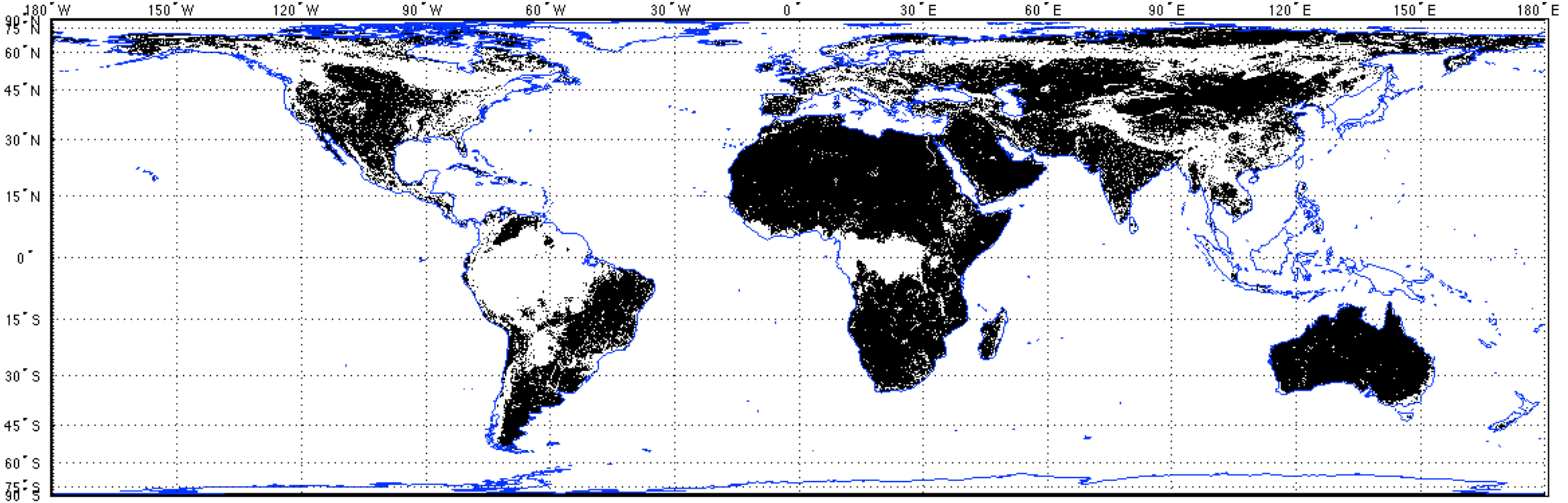
Soil Moisture Retrieval Map



Retrievable Mask (Black Colored Pixels) Prepared with Following Specifications:

a) Urban Fraction < 1
b) Water Fraction < 0.5
c) DEM Slope Standard Deviation < 5 deg

Soil Moisture Expected Accuracy



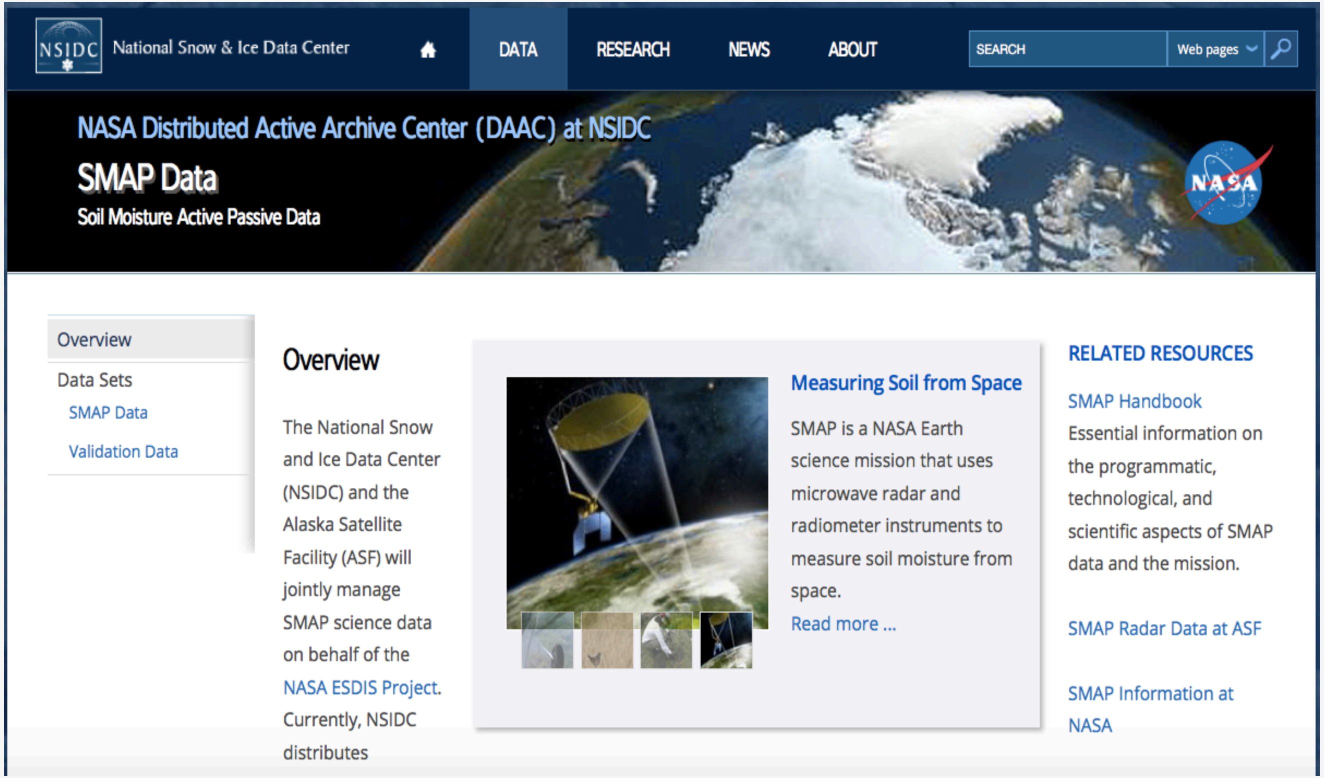
Retrieval expected quality mask (black colored pixels indicate good quality) with following specifications:

a) Vegetation water content ≤ 5 kg/m^2; b) Urban fraction ≤ 0.25

c) Water fraction ≤ 0.1; d) DEM slope standard deviation ≤ 3 deg

Access to SMAP Data: NSIDC

http://nsidc.org/data/smap/

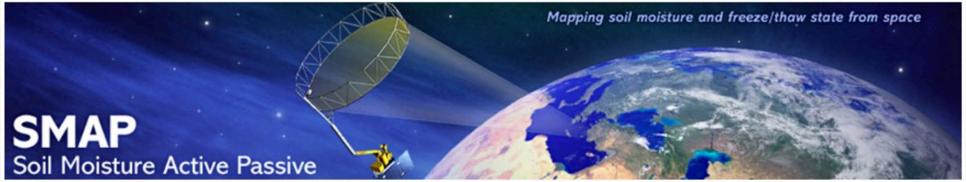


Access to SMAP Data: ASF

https://www.asf.alaska.edu/smap

- Sentinel-1
- SMAP
  - About SMAP
  - Science
  - Instrument
  - Applications
  - Data & Imagery
  - Documents & Tools
  - How to Cite
  - News & Media
- Seasat
- Wetlands MEaSUREs
- Sea Ice MEaSUREs
- Terrestrial Ecology
- InSAR
- ALOS-1 PALSAR
- RADARSAT-1
- ERS-1
- ERS-2
- JERS-1
- UAVSAR
- AirMOSS
- AIRSAR

SMAP



Data & Imagery

SMAP maps the world's soil moisture every three days. Data and imagery will be available at no cost to registered users at ASF DAAC (Level 1 radar) and NSIDC DAAC (Level 1 radiometer and all Levels 2, 3, & 4).

Read more...

Global Significance

SMAP data on soil moisture and freeze/thaw state will aid climate forecasting; flood, landslide, and drought monitoring; agricultural planning; and much more.

Read more...

Documents & Tools

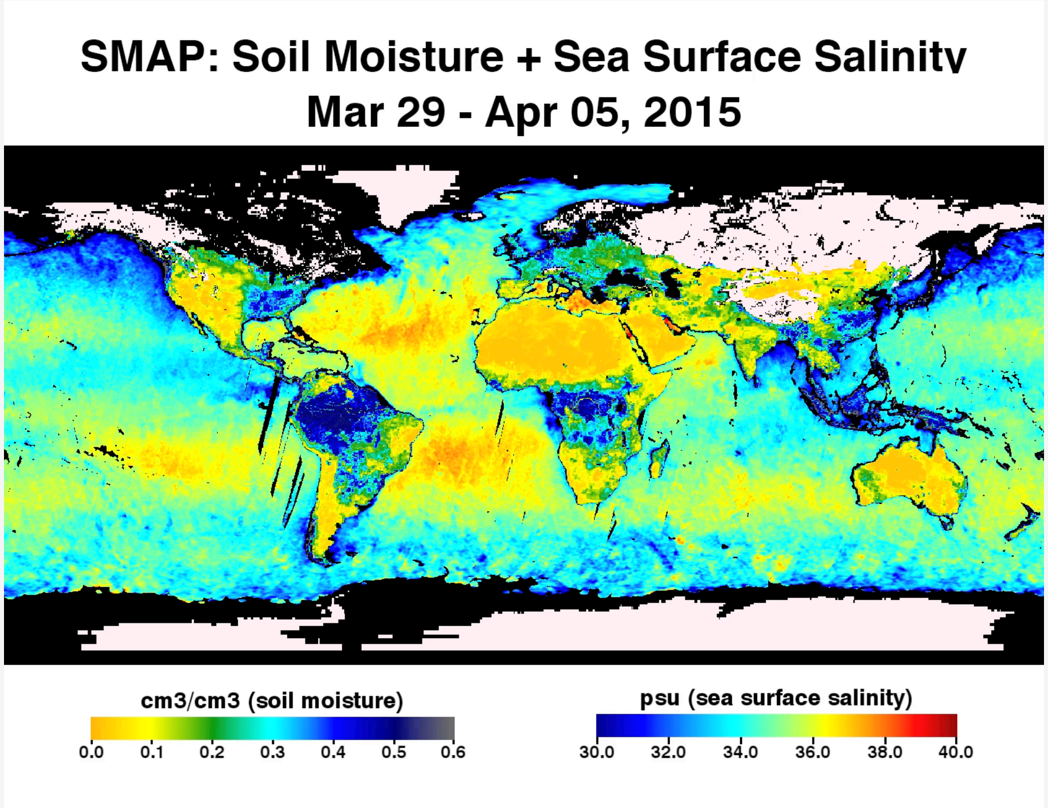
Access the ASF SMAP User Guide, the SMAP Handbook, tools such as MapReady, a table of ancillary-data reports with links to the data they cite, and more.

Read more...

News: NASA Soil Moisture Radar Ends Operations; Mission Science Continues
News: NASA Focused on Sentinel as Replacement for SMAP Radar

> *"A rare characteristic of the SMAP Project is its emphasis on serving both basic Earth System science as well as applications in operational and practice-oriented communities.*
> — SMAP Handbook

Global Soil Moisture Animation

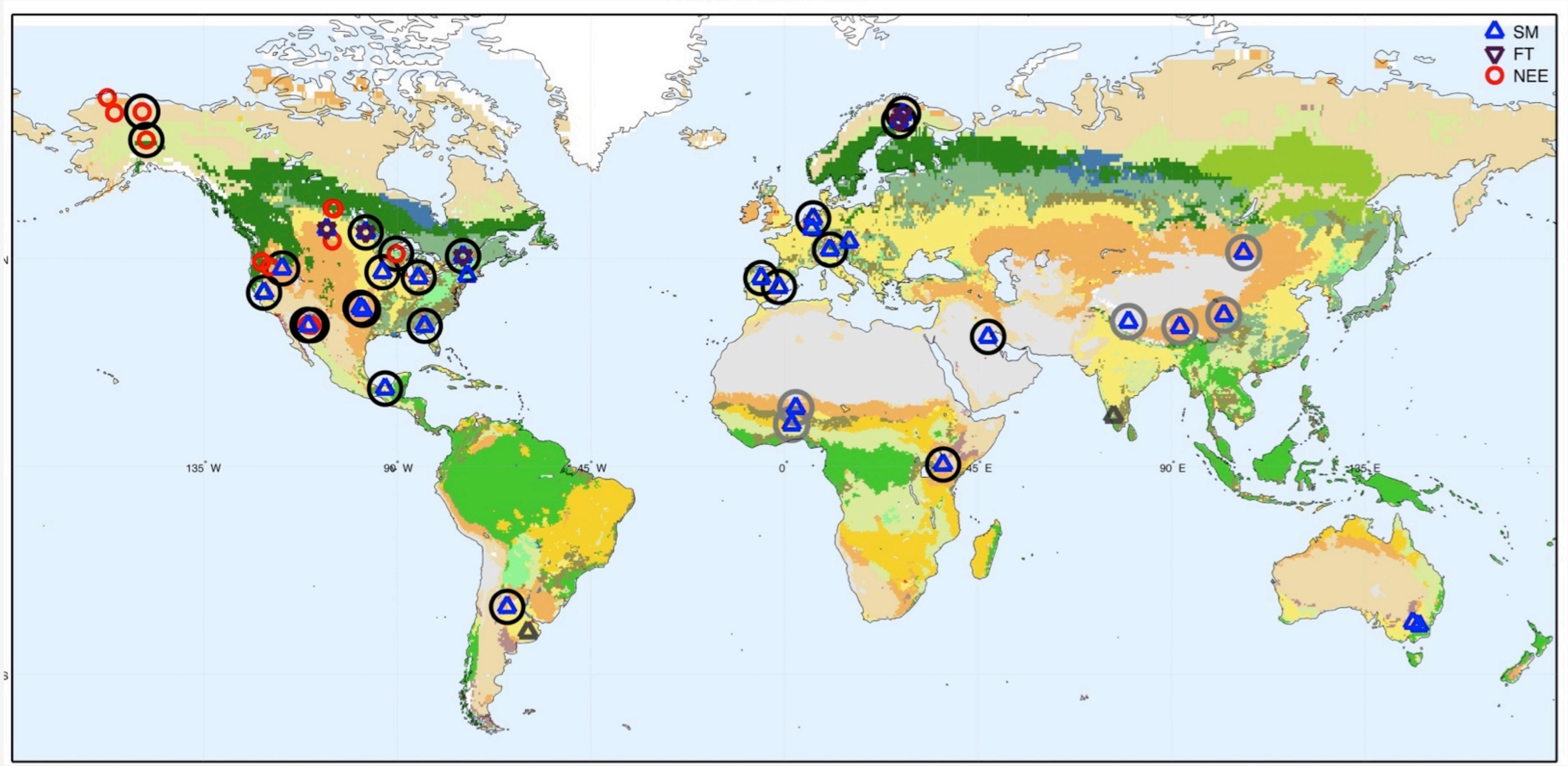


SMAP Calibration and Validation

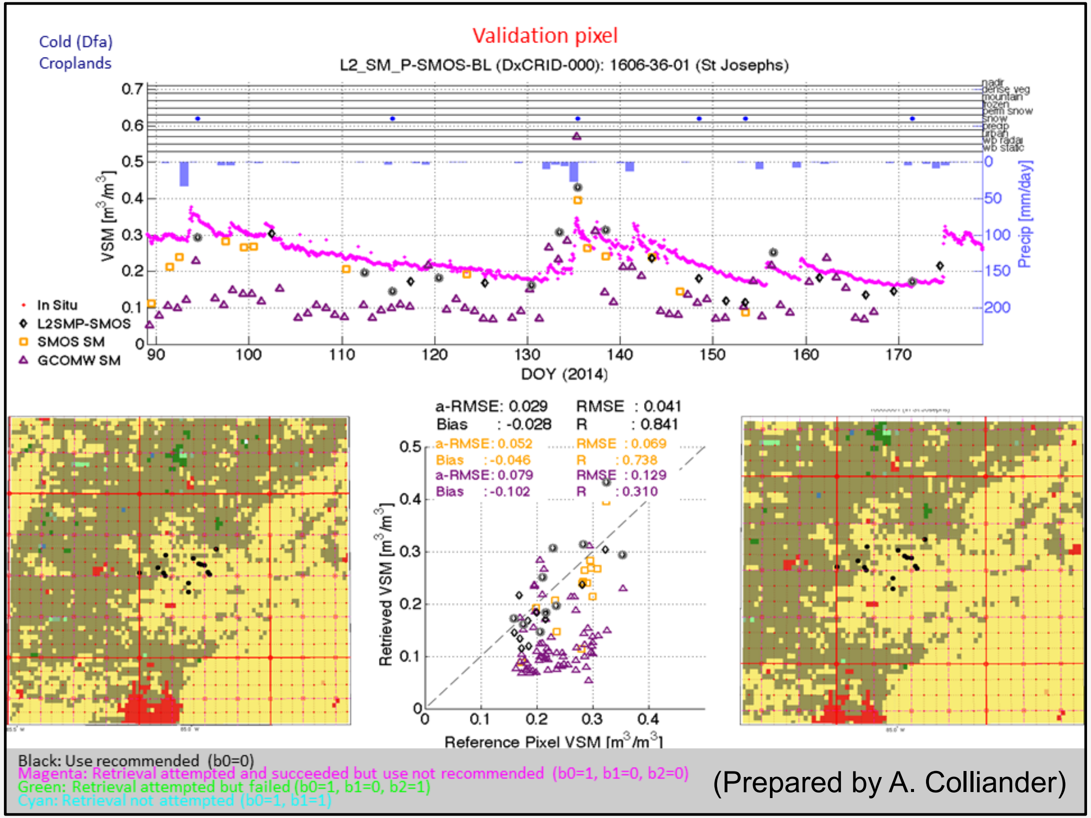
Cal/Val Methodology

Methodology	Role	Analysis tools and readiness
Core Validation Sites	Accurate estimates of products at matching scales for a set of conditions with spatially distributed in situ sensors	✓ Data transfer from Cal/Val Partners set up and/or automated ✓ Scaling methods defined ✓ Offset grid processing
Sparse Networks	One point in the grid cell for a wide range of conditions	✓ Triple collocation method tool completed ✓ Data transfer from Cal/Val Partners automated
Satellite Products	Estimates over a very wide range of conditions at matching scales	✓ Cross comparison tools developed for SMOS, GCOM-W and Aquarius ✓ Task Group formed
Model Products	Estimates over a very wide range of conditions at matching scales	✓ Developed high-res 3 and 9 km model products ✓ Statistical comparison methods developed
Field Campaigns	Detailed assessment of the scaling issues for a set of high priority conditions	✓ SMAPVEx15 and 16 campaigns defined ✓ Australia campaign in 2015

SMAP Cal/Val Sites

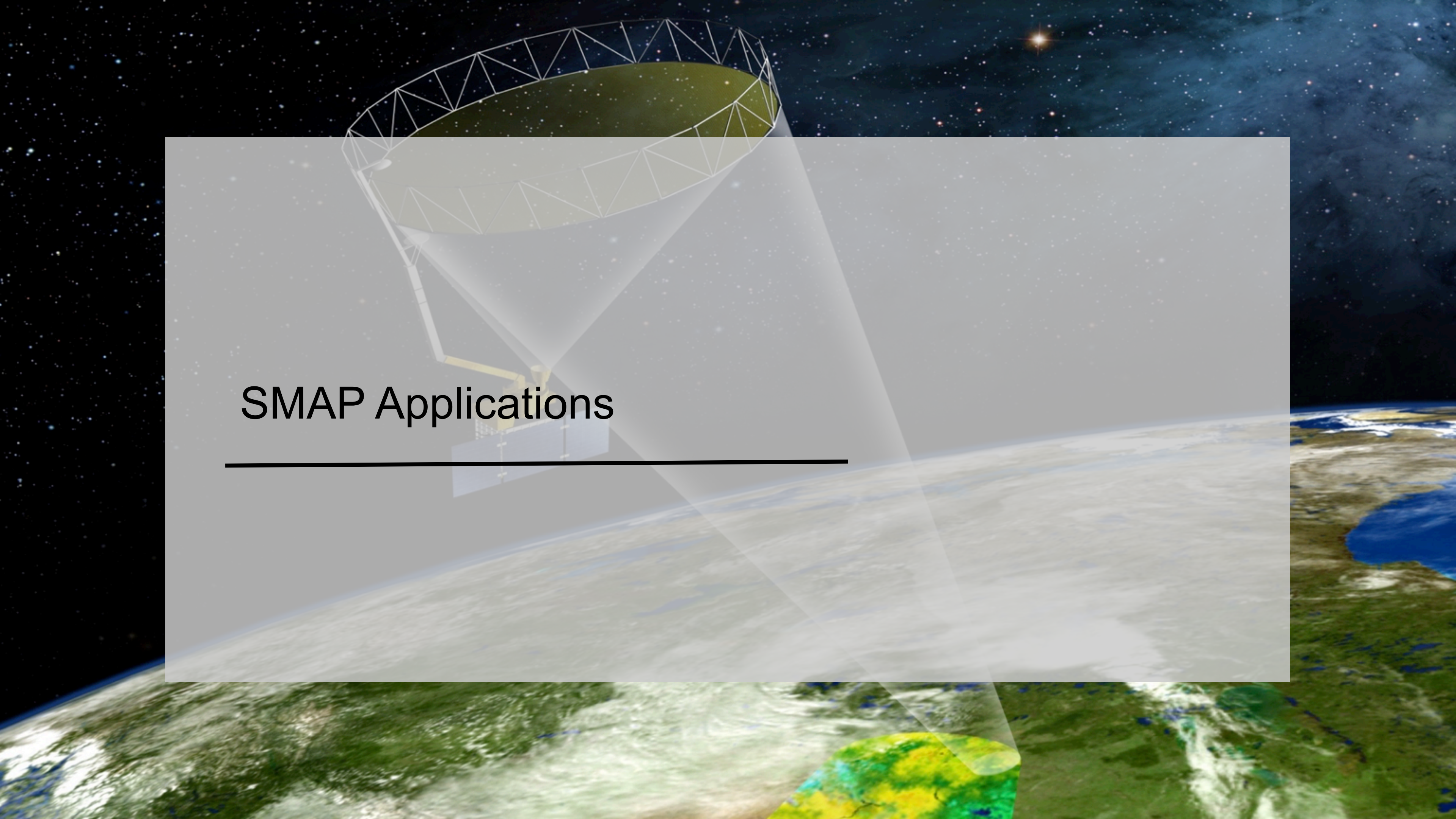


Comparison Between SMAP and In Situ Soil Moisture

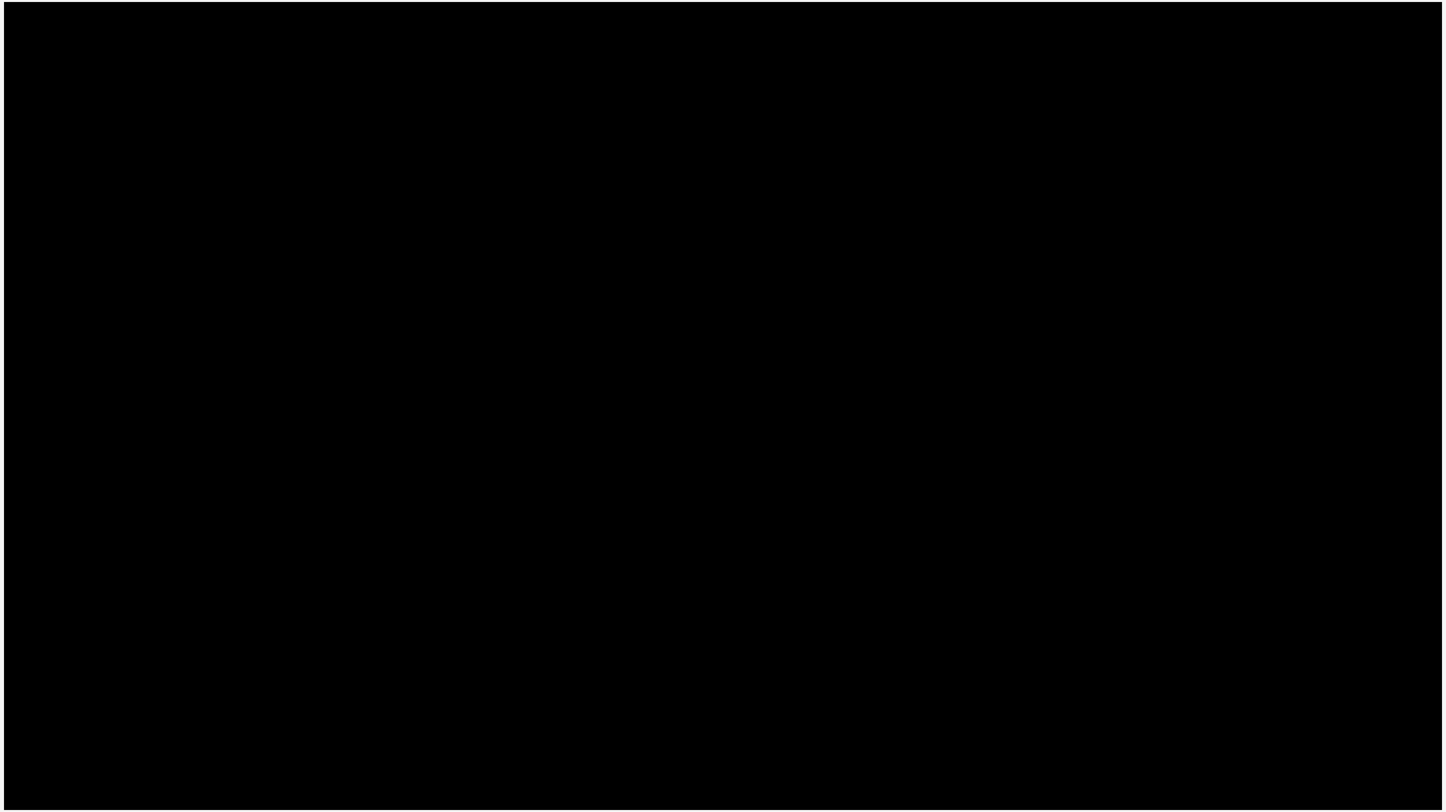


(Prepared by A. Colliander)

SMAP Applications



SMAP Video

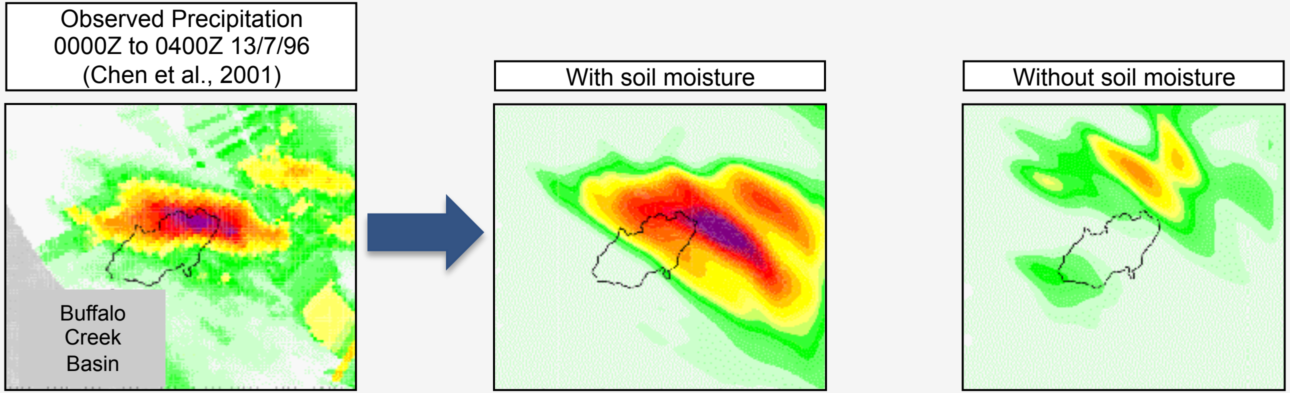


Value of Soil Moisture Data to Weather and Climate

Seasonal Climate Predictability

*Predictability of **seasonal climate** is dependent on boundary conditions such as sea surface temperature (SST) and soil moisture – **soil moisture** is particularly important over continental interiors.*

Rainfall Prediction

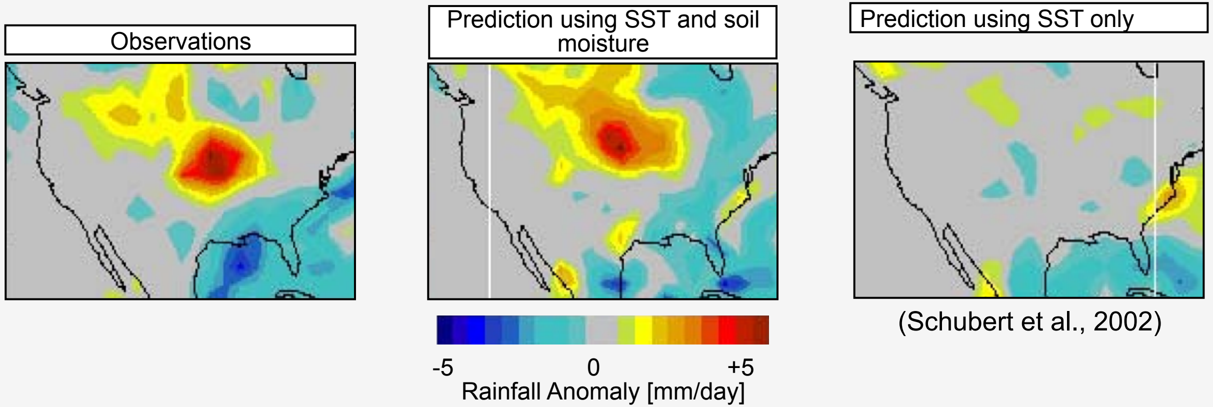


Value of Soil Moisture Data to Weather and Climate

Seasonal Climate Predictability

*Predictability of **seasonal climate** is dependent on boundary conditions such as sea surface temperature (SST) and soil moisture – **soil moisture** is particularly important over continental interiors.*

Rainfall



(Schubert et al., 2002)

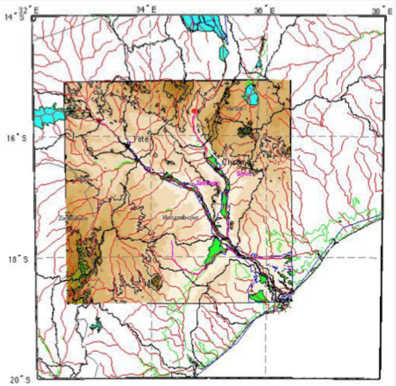
A Flood Example

Application of a SMAP-Based Index for Flood Forecasting in Data-Poor Regions

Current Capability: The UN-WFP uses satellite derived flood maps to locate floods and map delivery routes to affected areas.

Enhanced Capability: Use SMAP to expand their current flood database with look-up information that produces flood indices for a given rainfall forecast (ECMWF) and soil moisture condition (SMAP).

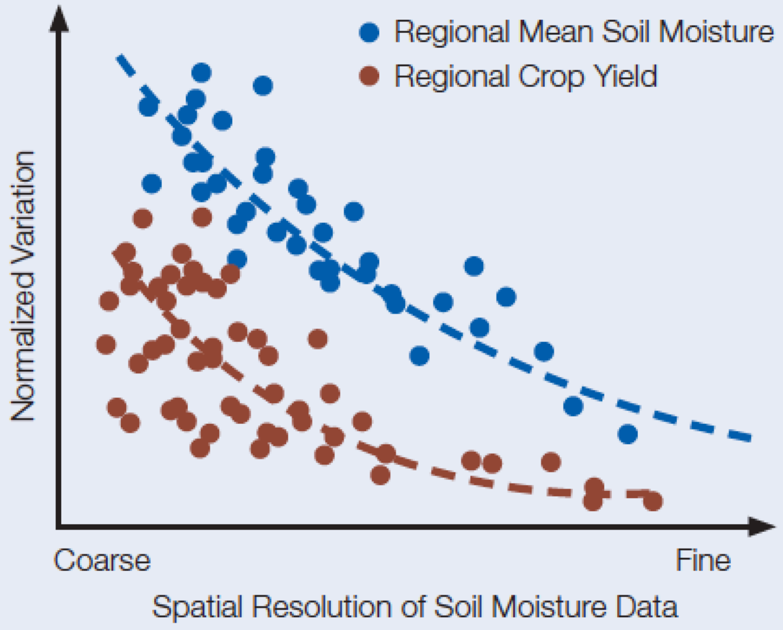
Study Area: Zambezi basin and its delta in Mozambique.



Courtesy of Guy Schumann- UCLA

Crop Yield Modeling

Agricultural models have been developed to predict the yield of various crops at field and regional scales. One key input of the agricultural models is soil moisture. The conceptual diagram relates variation in regional domain-averaged soil moisture to variation in total crop yield. Statistical analysis would lead to the development of probability distributions of crop yield as a transformation of the probability distribution of domain averaged soil moisture at the beginning of the growing season.



Predicting Vector-Borne Diseases

SMAP Applications Early Adopters

http://smap.jpl.nasa.gov/applications

SMAP Early Adopters video

This diverse group represents a cross-section of end-users of SMAP data who collaborate to ensure integration of SMAP data into operations that affect our day-to-day lives. Examples include the U.S. Forest Service, the UN World Food Programme, and the U.S. Department of Agriculture.

VTT files: English (VTT, 18 KB) | Italian (VTT, 18 KB) | Spanish (VTT, 19 KB)

Early Adopters

SMAP Early Adopters†, SMAP project contacts, and applied research topics. Many Early Adopters cross multiple applications.

Early Adopter PI and institution **SMAP Contact**	**Applied Research Topic**
Weather and Climate Forecasting	
* **Stephane Bélair**, Meteorological Research Division, Environment Canada (EC); SMAP Contact: **Stephane Bélair**	Assimilation and impact evaluation of observations from the SMAP mission in Environment Canada's Environmental Prediction Systems
* **Lars Isaksen and Patricia de Rosnay**, European Centre for Medium-Range Weather Forecasts (ECMWF); SMAP Contact: **Eni Njoku**	Monitoring SMAP soil moisture and brightness temperature at ECMWF
* **Xiwu Zhan, Michael Ek, John Simko and Weizhong Zheng**, NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS); SMAP Contact: **Randy Koster**	Transition of NASA SMAP research products to NOAA operational numerical weather and seasonal climate predictions and research hydrological forecasts
* **Michael Ek, Marouane Temimi, Xiwu Zhan and Weizhong Zheng**, NOAA National Centers for Environmental Prediction (NCEP), NOAA National Environmental Satellite Data and Information Service (NOAA-NESDIS), City College of New York (CUNY); SMAP Contact: **Chris Derksen**	Integration of SMAP freeze/thaw product line into the NOAA NCEP weather forecast models
* **John Galantowicz**, Atmospheric and Environmental Research, Inc. (AER); SMAP Contact: **John Kimball**	Use of SMAP-derived inundation and soil moisture estimates in the quantification of biogenic greenhouse gas emissions
◊ **Jonathan Case, Clay Blankenship and Bradley Zavodsky**, NASA Short-term Prediction Research and Transition (SPoRT) Center; SMAP Contact: **Molly Brown**	Data assimilation of SMAP observations, and impact on weather forecasts in a coupled simulation environment
Droughts and Wildfires	
* **Jim Reardon and Gary Curcio**, US Forest Service (USFS); SMAP Contact: **Dara Entekhabi**	The use of SMAP soil moisture data to assess the wildfire potential of organic soils on the North Carolina Coastal Plain
* **Chris Funk, Amy McNally and James Verdin**, USGS & UC Santa Barbara; SMAP Contact: **Molly Brown**	Incorporating soil moisture retrievals into the FEWS Land Data Assimilation System (FLDAS)
◊ **Brian Wardlow and Mark Svoboda**, Center for Advanced Land Management Technologies (CALMIT), National Drought Mitigation Center (NDMC); SMAP Contact: **Narendra Das**	Evaluation of SMAP soil moisture products for operational drought monitoring: potential impact on the U.S. Drought Monitor (USDM)
◊ **Uma Shankar**, The University of North Carolina at Chapel Hill – Institute for the Environment; SMAP Contact: **Narendra Das**	Enhancement of a Bottom-up Fire Emissions Inventory Using Earth Observations to Improve Air Quality, Land Management, and Public Health Decision Support
Floods and Landslides	
* **Fiona Shaw**, Willis, Global Analytics; SMAP Contact: **Robert Gurney**	A risk identification and analysis system for insurance; eQUIP suite of custom catastrophe models, risk rating tools and risk indices for insurance and reinsurance purposes


smap.jpl.nasa.gov